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Dynamic programming models for identification and measurement of inefficiencies in leasing arrangements

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DYNAMIC PROGRAMMING MODELS FOR IDENTIFICATION AND MEASUREMENT OF INEFFICIENCIES IN LEASING ARRANGEMENTS

by

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A Dissertation Submitted to the
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Major Subject: Agricultural Economics

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Ames, Iowa
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I. INTRODUCTION

A. Description of Leasing Arrangements

In all societies in which private property is prevalent, leasing systems are among the institutions which have an impact on the economic efficiency of food and fiber production. Leasing arrangements may also affect the distribution of national and agricultural income as evidenced in certain less developed areas[1] where agricultural tenancy is associated with wide income differentials.

A considerable part of the world agricultural resources is used on farms operated under different types of leases. It is estimated that tenants and their families amount to some 600 million people, that is about two-fifths of the world population engaged in agriculture (28, p. 1). In certain developed countries[1], tenancy may reach 77 percent of all farmers as in Scotland although it is much less prevalent in some countries like Denmark or Germany. In less developed nations, tenant farmers account for a considerable percentage of all farmers. Such is the case of India with 53 percent and Formosa with 40 percent. Thailand and parts of Indochina, however, show low percentages of tenancy. Latin America in which the "hacienda" tenure system is most prevalent presents certain modalities of peasant sub-tenancy which on the whole may be less significant than in other regions of the globe.

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[1]Less developed countries are defined in terms of the United Nations' concept of less than $100 per capita income per year. Developed countries refer to countries with $100 or more per capita income per year.

In the United States approximately one-third of all commercial farms are operated by tenants (40, p. 153). In certain midwestern states, e.g. Iowa, leased land comprises more than 50 percent of all farm land (4, p.5).

Even in highly developed economies rental arrangements are not only determined by the forces of the free-market but also by customs and the relative bargaining power of landlords and tenants. Therefore, it appears important to investigate the effects of different leasing systems on the resource allocation of agricultural enterprises.

1. Nature and functions of farm leases

Tenure systems can be defined as the manner in which rights in land are held by farm operators. These rights assure control of varying degrees over resources and are acquired by alternative means including ownership and pooling of resources among two or more individuals. Tenancy falls in the latter category which is only one of three major forms of land tenure, namely, tenancy, owner-operatorship and group tenure, and it (tenancy) may complement or substitute for owner-operatorship. In effect, rental agreements introduce flexibility in the tenure system, by providing means of modifying the size of the agricultural enterprise, steps toward acquiring ownership by landless farmers and also of transferring the farm from one generation to the other. The instrument through which landlord and tenant agreements are stipulated is the lease.

A lease is defined as a written or oral contract between a landlord (the one owning or controlling a tract of land operated by a renter) and a <u>tenant</u> or renter, the operator of the leased tract of land, concerning use of resources for a given period and a specified payment (19, p. 83).

The lease, by providing an institutional framework within which individuals can pool their resources and work together as a team, performs various functions. This study is concerned primarily with the economic function. In a price economy the lease acts as an allocator of resources between different production plans. It also has the important function of allocating income between the landlord and tenant. A lease is considered efficient or "perfect", if its terms allow for an allocation of both landlord's and tenant's resources in the same way as they would be allocated on an owner-operated farm. Besides, the "perfect" lease requires that the total income obtained by both landlord and tenant on a leased farm must be equal to that earned by an owner-operator who maximizes the net value of the farm output from given resources at existing input and output prices.[1]

Thus, the lease may perform a decisive role in arriving at an efficient allocation of resources and at an equitable distribution of returns.[2]

However, a lease has other functions which are also important. Timmons calls them social functions (30, p. 9). These are the following: 1) It permits tenants with limited resources to begin farming. This is of

[1]These conditions for efficiency of a lease will be analyzed in detail in Chapter II.

[2]An equitable distribution of income is defined as that which assures the resource contributor the marginal return of his resource. However, this definition may have little application in certain less developed countries in which the marginal productivity of the tenant labor is so low that it provides insufficient means of survival.

special interest if society adopts as one of its goals the access to ownership through tenancy by farm operators; 2) It might make good use of superior training and experience of landlords who can offer their advice to young farmers; 3) In case of agrarian reform, it constitutes an orderly means of transferring use and occupancy rights in property. It is also a means of transferring farms from father to son; 4) A well conceived and adequately implemented leasing arrangement may bring about the strengthening of democracy in the so-called less developed countries through the elimination of social unrest.

2. Types of leases

Leases vary widely between different countries and between regions of the same country. Since the empirical part of this study will be confined to the Midwestern United States, only a brief description of the most common leases of the United States will be presented. A cash lease is one in which the specified payment is an amount of money. In other words, the landlord receives a fixed cash rent for the entire farm or tracts of land and the tenant gets all the receipts thereof.

A crop-share lease provides payment to the landlord in the form of a share of the crops and a crop-share-cash lease adds, in addition to the share of crops, a specified payment as cash rent. The usual crop-share lease provides for the sharing of receipts and expenses on a 50:50 basis for most crops. The fixed cash-rent received under a crop-share-cash lease by the landlord usually comes as a rental payment for hay and pasture land; the tenant obtains all the returns from those two latter enterprises. A livestock-share lease is an agreement by which the income from both livestock and crop enterprises is shared by the landlord and tenant. Usually the farms under this type of lease have livestock production as their major source of income. (19, p. 83).

It can be noted that the soundness of a tenancy system, as well as any other agrarian structure, is related to economic efficiency and economic development of the country in which that system is established. In effect, institutions which in a complex society are needed to regulate the action of the individuals can have impeding or beneficial effect on the efficiency of the economy and thus affect its rate of economic growth.

B. Previous Empirical Research

In recent years, considerable research has been undertaken in the United States to determine empirically the nature and magnitude of the misallocation of resources within firms resulting from leasing arrangements. The misallocation of resources or inefficiencies can be expressed in terms of deviations within the existential situation from the norm of optimal efficiency for a leased farm provided by economic theory.

The general approach to these problems consists of three steps: 1) Establish the proportion of the deviations from optimal conditions in resource allocation, that can be attributed to leasing systems *per se*. However, other factors such as price and yield uncertainties, managerial ability, may also have an impact on economic efficiency. Therefore, this first step has a delimiting character. 2) Discover how the different tenure classes or sub-classes account for the gap, between the norm and the actual situation, which can be attributed *per se* to tenure arrangements. This second step has the character of a diagnostic hypothesis and its purpose is to isolate the effects of different tenure factors -- type of lease, length of lease, mortgage encumbrance, etc. -- and measure their impact on resource allocation. 3) Test remedial hypotheses in order to find arrangements compatible with optimum resource allocation.

The principal research projects have made use of three types of techniques (37): descriptive analysis mainly based on interview surveys and secondary data (2, 4, 18, 19, 31), single equation models for marginal analysis (11, 14, 25), and finally linear programming (5, 13, 24, 28).[1]

The first class of technique has been used with success. The sources of evidence may include farm records kept by local or state business associations, field interviews with tenants and landlord, written questionnaires sent by mail, related research studies, United States Census of Agriculture reports, and cost, price and production data on file in crop and livestock reporting services. The Hurlburt study is a good example of this type of research (19).

The second empirical procedure uses single equation models, i.e., production functions fitted to the data obtained from stratified or purposive farm samples. It usually consists of two parts: 1) A general analysis which outlines the main features of the tenure systems investigated. The tenure classes considered in these studies have been the "typical" ones of each region; 2) The estimation of the degree by which each tenure or lease system achieves the efficient norm in resource

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[1]This classification evidently is not a clear cut one. There is a certain overlapping in the methods and goals of the three techniques. The first two techniques are more of a positive type of analysis and the last one is more of a normative nature.

allocation. Most of the studies use Cobb-Douglas functions fitted to data obtained from the farm samples, by means of regression analysis.

The main results of the studies conducted in the Midwest show that among factors of production, capital services is the limitating factor for owner-operators, and land for livestock and crop-share renters (11, 14, 25).

The single equation models employed to estimate tenure parameters and appraise the efficiency of the leasing system present certain advantages but they also possess some serious limitations. These are due to problems of aggregation of inputs and outputs, of the failure to include in the function certain variables such as managerial ability and, also, quality differentials of the labor input are usually disregarded. These limitations raise serious doubts about the significance of the results obtained from Cobb-Douglas functions.

All the disadvantages mentioned with regard to single equation models perhaps have made researchers turn their attention to a relatively new technique in approaching problems of land tenure and economic efficiency. Linear programming even if not a substitute for single equation models, has proved to be a useful technique. The underlying assumptions of the two models are different and their purposes are also different. The production function gives factual information about a given situation. It is, therefore, a part of so-called positive economics. Linear programming strives to obtain a certain optimum production plan for a particular firm, given some limitations in resource availability and having a specified end to maximize (6, 12, 36). This technique belongs rather to a normative type of economics .

The technique is called linear programming because it maximizes (or minimizes) a certain linear function (profits or costs) subject to certain restrictions or limitations. The choice criterion is usually the net prices of products (or the prices of factors). Linear programming supposes the existence of alternative ways or possibilities in the combination of resources and products. To use linear programming efficiently, there must be several production possibilities because if there were only a few alternatives, budgeting could successfully replace linear programming. These alternatives are called activities or processes: it is assumed that each combination of resources along a production function is a different activity. Another important feature of linear programming is that it deals with short-run situations and therefore with firms which have a fixed plant and are subject to limitations in land, capital, etc. It also assumes constant returns to scale.

Taken as a guiding criterion the necessary conditions for leasing efficiency, namely that the optimum plan for tenant and landlord must be the same, and the sufficient condition, that the optimum plan for the farm as a whole, given a certain quantity of resources, must coincide with the optimal plans for both the tenant and landlord, the linear programming method can give answers to questions such as, which leasing arrangement most nearly allows an efficient use of resources under various resource situations - main and collateral situations - or how efficient are typical share leases? This method has been used by Heady and Egbert (11). Timmons and De Benedictis have introduced a modification which permits us to follow the intermediary positions between the landlord and tenant optima (5).

It is important to note here that all the research models examined above assume free competition, certainty of price and yield expectations and a timeless analysis. It is convenient to carefully evaluate these assumptions.

The first assumption implies that there is no collusion between buyers or sellers in the market and that the prices duly reflect the consumers' preferences. However, this assumption is not extended to the market imperfections arising from the leasing systems themselves. In certain cases either the landlord or the tenant have more bargaining power than the other. Consequently, the rent for land services, or the manner of sharing costs and returns can vary within certain limits. This situation existing between the landlord and tenant evidently has some elements of bilateral monopoly. It is also known that perfect competition is non-existent in wide sectors of the American economy and that prices, in this era of production controls and subsidies, do not fully reflect consumers' choices. Therefore, the pricing system does not always lead to an optimal allocation of resources.

The second assumption is even more unrealistic in agriculture than the assumption of free competition. Price fluctuations causing uncertainty of expectations are common in the agricultural sector, in particular those affecting livestock. Yield uncertainties are particularly associated with crop enterprises. Stochastic rather than the deterministic models that have been mentioned could perhaps enhance accuracy and relevancy of analytical results.

However, even if the first two assumptions are not completely justified by factual experience, the conclusions obtained from the research using those assumptions are not unwarranted. The reason is that if the effect *per se* of leasing systems upon efficiency is studied, those effects have to be precisely isolated from the rest of the variables by keeping the latter fixed. Evidently, the ideal is to relax as much as possible the stringent assumptions.

The third assumption regarding time can be justified only in the case of intra-temporal analysis of resource allocation. But if the effect over time of leasing systems on efficiency is investigated, it becomes evident that the same assumption would be completely invalid.

Precisely, in this field of inter-temporal inefficiencies there is a serious gap in research. The reason may well be that dynamic models are relatively new in economics and they certainly are more complex, computationally, than the static ones. Some applications have been made to farm planning by using dynamic linear programming (20,26). However, there has been little research with regard to rented farms under different leasing arrangements, other than studies of a more delimiting character which have consisted of tabulations and simple statistical tests of the number of years of expected occupancy of tenants, the provisions for compensation for unexhausted resources in case of cessation of contract, percentage of written leases, etc.

It is therefore apparent that a need exists for research which explores inter-temporal inefficiencies caused *per se* by leasing arrangements. In particular the impact of uncertainty of tenure due to short-term leases could be investigated. The condition for efficiency in a dynamic sense is that the planning period of the tenant must coincide with the optimum planning horizon for products within the firm (34). In other words, the cultivator must have a lease covering a period of time that permits him to realize all the expected returns from his investment or he must otherwise be assured of compensation for his investment. The importance of the problem of limited planning horizon is illustrated by the data taken from a sample of 275 farms of Midwestern states shown in Table 1.

Table 1. Expected farm occupancy by tenure classes in four Midwestern states.

	Expected years of occupancy			
Tenure class	0 years[a]	1 to 2	3 to 5	over 5
Crop-share lease	13	53	47	58
Livestock-share lease	5	19	38	42
Total	18	72	85	100
Percent of total operators	6.5	26.2	30.9	36.4

Source: U.S.D.A. and North Central Regional Land Tenure Research Committee

[a]Includes 0 years and also no answer.

It is clear that if more than 30 percent of the operators have a very short-term lease of two years or less without compensation clause, as is the case for most of them, then lease-engendered inter-temporal inefficiencies become serious.

C. Objectives of This Study

Having described the nature of the problem reviewed in previous research, we come to the specific objectives of this study. These objectives are:

1. To develop a method of dynamic linear programming that permits the introduction of t years of activities and restrictions ($t = 0, \ldots, n$) in order to observe the effect of time on resource allocation on a rented farm under different leasing arrangements and also on one operated by the owner.

2. To obtain optimal six-year plans, in an <u>ex-ante</u> sense for owner-operators, landlords and tenants employing alternative levels of fertilization, conservation and livestock investment in order to observe the pattern of resource allocation through time. It is assumed that a six-year planning horizon is adequate. Furthermore, allowances are made for the amount of resources diverted from production by the family living on the farm.

3. To obtain three optima and consecutive two-year plans covering the same period of time as the previous six-year programs. These plans should optimize returns to both the tenant and the landlord.

4. To delineate and to measure the problematic areas created by intertemporal inefficiencies or dissociations within the lease by comparing the returns of the long-term plans and the short-term plans. Intra-temporal inefficiencies or dissociations will not be studied. In this respect the study complements the Timmons-Benedictis study mentioned earlier (5); and

5. To identify the factors responsible in creating the gap between the ideal or norm and the actual situation, and also to investigate their behavior.

D. Methods and Procedures

The procedure used to carry out the objectives of this study is composed of three consecutive steps. The first step is a theoretical analysis of the dynamic theory of the firm. The need to examine the validity of firm theory assumptions when institutional factors such as leasing arrangements come into the picture is stressed. In particular, the assumption of perfect association of benefits and costs in the person of the entrepreneur is questioned. Also a review of the main contributions to the theory of leasing systems is presented. From this analysis a set of hypotheses is obtained. These hypotheses will be tested in an empirical case situation.

The second part is the elaboration of a dynamic model of linear programming. It will provide the framework within which inter-temporal inefficiencies or dissociations of benefits and costs on the leased farm may be studied.

The third part consists of the analysis of the effects of crop-share leases upon the efficiency of resource allocation in the area chosen for the study - the Midwest. Crop-share leases are most numerous in that area.

1. Area of study

The farm selected for study is located in Fremont County in Southwestern Iowa. The following procedure was used in selecting that farm. Empirical data of a comprehensive interstate survey on the relative efficiencies of leasing systems were available. The survey was undertaken under the auspices of the North Central Regional Land Tenure Research Committee composed of 13 state agricultural experiment stations and the

Farm Foundation, by the United States Department of Agriculture and four cooperating states, Missouri, Iowa, Nebraska and Kansas, which are members of the regional committee. The name "MINK" study, by which this survey will be referred in the remainder of this report, is derived from the first letters of the above four states. Ample information was available with regard to the physical, technical, economic and institutional conditions of the area covered by the study which comprised a relatively homogeneous section of the deep loess soils of Northwest Missouri, Southwest Iowa, Southeast Nebraska and Northeast Kansas. The Iowa section of the MINK study included a sample of 201 farms in Fremont, Page, Montgomery, Mills and Pottawattamie Counties, all of them belonging to the Marshall Soil Association and having similar weather conditions and methods of farming. Table 2 shows the number of respondents to the MINK study survey by tenure class.

Table 2. Number of respondents in the Iowa section of the MINK study by tenure class

Tenure class	Number
Owner-operators	67
Crop-share renters	77
Livestock renters	57

The information obtained from these farms provided criteria for the selection of a farm which, as far as possible, would be representative or typical in terms of soil type, farm size, amount of building space, machinery facilities, cropping enterprises, etc. Institutional restrictions taken from the MINK study have been incorporated in this research.

2. Source of data

The large bulk of information regarding the institutional and other restrictions such as type of lease, level of capital and labor, livestock building space, machinery and equipment, etc., as expressed above, came from the Iowa section of the MENK project. The crop yield data were obtained from estimates made by the members of the Agronomy Department, Iowa State University, using three levels of fertilization - insufficient, low and high, and three levels of conservation - no conservation, contouring and terracing, for each rotation and different type of land within the farm. The livestock input-output coefficients were obtained from the Animal Husbandry Department, Iowa State University. The terracing costs estimates were obtained from the Agricultural Engineering Department, Iowa State University. The prices of agricultural inputs and outputs were derived from the United States Department of Agriculture monthly reports. A simple expectation model, the mean value of the years 1955-1959, was developed as the operator's set of expectations for input and output prices.

3. Analysis of data

The ordinary linear programming technique - simplex method - is used to determine farm plans which will maximize returns both the tenant, landlord and owner-operator. The only novelty is that the number of activities or columns of the matrix, and the number of rows representing restrictions is highly increased. The reason is that activities or restrictions of different years are considered as altogether different activities. Therefore, the problems can be handled only by an electronic computer. The use of *a-priori* economic knowledge about the problems simplifies somewhat the computational complication. In this phase of the study, the Statistical Laboratory of Iowa State University has cooperated.

II. THEORETICAL FRAMEWORK FOR ANALYSIS

A. The Hicksian Dynamics

A firm is a decision-making unit. The entrepreneur decides the kinds and amounts of commodities he will produce, and the methods of production he will use. He transforms inputs into outputs according to the technical possibilities open to and recognized by him. He is responsible for his decisions and therefore obtains a profit or bears the loss from each part of the production process.

A firm is in equilibrium when the entrepreneur has no reason to alter through time the production plan adopted, after having considered the input and output prices of the present and the price and technological expectations for the future. Static economic theory proposes certain conditions for timeless equilibrium. Hicks adapts them to a dynamic framework by defining a period of time, the "week", during which variations in prices are negligible.[1] He assumes that every individual has single-valued expectations of all relevant future prices.[2] However, he does not neglect completely the uncertainty of expectations which ordinarily affects the planning agent at the moment of decision-making. In effect, for Hicks the representative price is not the most probable price but rather the most probable price plus or minus an allowance for uncertainty (17, p. 124). He calls the latter "risk premium" and it is determined not only by the

[1]He further assumes that in each period temporary equilibrium is easily reached in the market and that each individual possesses perfect contemporaneous knowledge of the prices.

[2]This, of course, implies perfect competition.

planning agent's anticipations of future prices but also by his willingness to take risks. Thus the entrepreneur's "certain expectations" are rather those which represent the state of uncertainty in which he makes his plans for the future.

The entrepreneur, at the beginning of a particular period, establishes a production plan, viz. the amounts of inputs consumed and outputs produced during the n future periods (17).[1] Many alternatives or plans are open to the entrepreneur. Since in perfect competition his expectations are not related to a whole demand schedule but rather to a single price, the impact of the future upon the present behavior of the firm depends solely on the same entrepreneur's technological and price expectations. He can thus determine which plan is the most profitable.

The entrepreneur will choose one production plan over the others according to a simple criterion, the present capitalized net value output of the chosen plan must be the greatest. Hicks defines the surplus of any planning period (week) as the amount by which the present value of output exceeds the present value of inputs. If interest rates and interest-expectations are given, the total capitalized value of the n + 1 flow of surpluses is:

$$C = \sum_{r=1}^{r=n} \sum_{t=0}^{t=n} \left(\beta_t^t \, p_{rt} \, x_{rt} \right)$$

Where $\beta = \dfrac{1}{(1+i_t)}$ and i_t is the rate of interest per week for loans of t

[1]According to Hicks, an input is anything bought by the firm and an output anything sold.

weeks; p_{rt} is the expected price of the r^{th} product in the t^{th} week and x_{rt} is the output of the r^{th} product for the t^{th} week.[1]

Hicks, by considering outputs of different periods as different outputs, and inputs of different periods as different inputs and by using discounted prices for the same inputs and outputs, shows that the conditions for equilibrium of the firm are the same in the dynamic case as in the static case. These conditions are three (17, p. 197):

(1) The marginal rate of substitution between outputs of any two dates must equal the ratio of their discounted prices;

(2) The marginal rate of substitution between inputs of any two dates must equal the ratio of their discounted prices; and

(3) The marginal rate of transformation of any input into any output must equal the ratio of their discounted prices.

These are necessary conditions but not sufficient. The sufficient or stability conditions are:

(1) There must be an increasing marginal rate of substitution between outputs;

(2) There must be a decreasing marginal rate of substitution between inputs; and

(3) There must be a decreasing marginal rate of substitution of an input into an output.

There is an additional dynamic condition that the present value of the flow of surpluses must be positive. This, as a side consideration, fixes the length of the planning period.

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[1]The price is discounted for risk as expressed above.

B. The Assumption of Perfect Association of Benefits and Costs

From the above presentation, it is clear that the theory of the firm assumes perfect association of benefits and costs. In effect, the decision-making act and its consequences are attributable to the same person, the entrepreneur. This means that the input contributor receives a full share of the returns earned by each unit of resources he contributes. However, as Hicks himself acknowledges, the analysis of the firm is done "without inclusion of reference to institutional controls" (17, p. 7). These institutional controls will permit the agricultural firm, for instance, to take the form of an owner-operated farm, a leased farm, a corporation, a watershed or a vertical-integrated farm. Hick's assumption is a severe assumption and he defends it on the grounds that the study of economic institutions is better undertaken by methods other than economic.

Institutions defined as "group control exercised on and in making and carrying out individual and group decisions" are the framework within which economic decisions are made or implemented (33, p. 169). Furthermore, they may have favorable or adverse effect on the outcome of individual actions. Therefore, they cannot be excluded when analyzing actual problems. Otherwise, theory may become a sort of intellectual exercise with little relevance to the problem studied.

The assumption of perfect association of benefits and costs in the theory of the firm is warranted as long as institutional factors are excluded from the analysis. But if not excluded, the assumption may no longer hold. The case of the farm, which is the main interest of this pursuit, illustrates well the point. This assumption is justified for the owner-operator who can attain optimum allocation of resources while maximizing his profits.[1] In a rented farm under customary leasing arrangements the situation is different. There resources are separately furnished by land-owner and tenant. The decision-making act is not in the hands of a single entrepreneur as the theory of the firm assumes. It is split between lessor and lessee, varying according to the type of lease and the relative bargaining power of each party. In practice, cash leases leave most of the decisions in the hands of the tenant. Crop-share leases permit the tenant to make some of the decisions and the landlord, others. Livestock leases tend to resemble a partnership between tenant and landlord. Consequently, the decision power belongs here to both landlord and tenant, although pending an agreement specific responsibilities are usually shared between them

From the above it can be shown that perfect association of benefits of costs ordinarily does not exist in a rented farm. In effect, there are two types of dissociations conncected with leasing arrangements (29, p. 1178). The first occurs within a certain period of time. In economic terms, it is a short-run or intra-temporal dissociation. The second is one which comes about between individuals over several periods of time. It is called an inter-temporal dissociation.[2]

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[1]Making allowances for inter-farm dissociations. An example of the latter: two adjoining farms in which one of the farmers causes flood and siltation damage to the other.

[2]Both types of dissociations may occur either within a single firm or between firms. This study is concerned only with the first.

An example of intra-temporal dissociation is a leasing arrangement which permits the sharing of products between the landlord and tenant in a different proportion. Take for instance a hypothetical share-lease which stipulates that the sharing ratio for soybeans is 60-40 for the tenant and landlord and for corn is 50-50. If all costs are shared on a 50-50 basis, the tenant will be stimulated to plant more land in soybeans since he can shift the costs to the landlord or, rather, he receives a higher share of soybean returns.

A frequent inter-temporal dissociation on a rented farm is the one connected with short-term leases. Benefits arising from the tenant's investment in the farm are shifted over time to the landlord, after the lease expires, if there is no compensation provision in the lease.

The above indicates the need to study the equilibrium conditions for the firm when a leasing arrangement is present.

C. The Theory of Leasing Systems

Additional conditions for equilibrium in the rented farm have been presented by Heady (9, 10). He defines the "perfect" or efficient lease as "one which allows the same farm plan to be most profitable for the landlord and the tenant; this plan should also be the one which is optimum for the farm as a whole" (13, p. 937).[1] Underlying this definition are the usual assumptions of perfect competition and that the price system is an adequate expression of consumer preference, and hence, an appropriate means of allocating resources in an efficient way.

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[1]An owner-operator with a large mortgage encumbrance could be less efficient than a tenant. Therefore, this is only a relatively perfect lease.

The above definition provides a starting point for setting conditions or rules by which leases can be judged under the point of view of farming efficiency. Hurlburt conveniently calls them "incentive conditions" because any lease must conform itself to them in order to encourage operations which will maximize income from the combined resources of tenant and landlord (19, p. 86). If these conditions are not realized two alternatives are possible. Either, the landlord and tenant maximizing the resources contributed separately by each of them, will not jointly attain the same level of profits as when the same amount of resources are maximized under owner-operatorship, or, the farm will be operated at an optimum level of resources use, but with the presence of income transfers from one resource owner to the other.

The four incentive conditions are:

1. "The share of the factor of variable input must be the same as the share of output of product obtained from it." An example will show why this condition must hold in order that the tenant or landlord invest the optimum amount of capital or other resources. Assuming that fertilizer is necessary for profitable corn production and that a 50-50 sharing of the product has been agreed to between the landlord and tenant, then a sharing of costs other than on a 50-50 basis changes for the tenant or landlord the level of most profitable application of fertilizer. If the tenant bears all the costs and only gets a half of the returns, he will apply fertilizer only until the marginal unit of input has equal value as the marginal unit of his share of corn. This results in less profits for the firm than would be the case if the tenant paid only half of the costs: no dissociations of benefits and costs could be then engendered

by the lease.

2. "The shares of all products must be the same." In share leases, a differential share of products stimulates resource owners to maximize their own resources in such a way that either the landlord or the tenant will try to produce more of the crop of which he has a larger share. This will result in a lower total income than if the two crops were produced at the point where their marginal rate of transformation is equal to their price ratio. This evidently supposes that the two crops are competitive although this condition also holds even if the crops are complementary or supplementary (9, p. 601).

3. "Each resource owner must receive the full share of the product earned by each unit of resource he contributes." Equity, in an economic sense, implies that the input contributor receives a full share of the return earned by each unit of resources he contributes. This assures a perfect association of benefits and costs for the resource owner. The third incentive condition is nothing more than an application of the equity concept to the fixed and variables resources of landowner and tenant on a leased farm.[1] A typical example of violation of this clause is the fact that living facilities are not separated from production facilities and no specific rent is charged for them, or landlords, in certain crop-share leases, who contribute certain specific inputs for the tenant's livestock enterprise and do not get any returns for them.

4. "Each resource owner must have an opportunity to receive return

[1] The same reservations with regard to the concept of economic equity or justice are expressed here as in Chapter I.

on investment made in one production period but not forthcoming until a subsequent period." This fourth condition should be present in any lease in order to prevent inter-temporal dissociations within the firm. This implies that the tenant must have an optimum planning horizon or must be compensated for expected returns from any investment should he move before the total amount of returns is realized. Suppose a tenant wants to invest in equipment, buildings or conservation practices. If the lease term is long enough or if there is a compensation provision for unexhausted investments, then the renter will be stimulated to make those investments.

In this connection, it is important to note, that not only investments will be deterred if the lease does not fulfill this condition, but also that the choice of enterprises opened to the tenant will be reduced. It is not logical to think that a tenant will get started in a new venture, say dairy, a long rotation or any other enterprise which needs special equipment or time to be built up, unless he possesses reasonable security of tenure over a period of years. Even if he could reasonably expect that in case of cessation of contract, he will be able to rent another farm in which he could continue that same enterprise, he is never quite sure that the new farm will have the same characteristics as the old one with regard to soil, weather, distance from the markets and many other imponderables. Therefore, he has to resign himself to undertake other enterprises which may be less profitable or less attractive.

1. The "perfect" lease

A lease which meets the four incentive conditions is called a "perfect" lease.[1] This "perfect" lease is somewhat different from the prevalent concept of crop-sharing arrangements. In effect, in certain aspects and due mainly to the first condition requiring the sharing of costs as well as of returns between lessor and lessee, crop-share renting tends to acquire some of the characteristics of a partnership such as those which a livestock share-lease already possesses. In practice, what would be the significance of a change towards a "perfect" lease? If the latter becomes more widespread, it may have some psychological and legal consequences, besides the expected economic effects. The tenant may be made liable for the losses incurred by the landlord and vice-versa. This could produce reluctance from the part of both parties to embark on such a venture.

The tacit understanding that under a share-crop lease the tenant is not liable for losses incurred by the landlord could be broken by the introduction of a perfect lease akin to partnership. Besides, a perfect lease which forces the landlord upon a sort of partnership extended through a relatively longer term of time (or, alternatively, upon a lease with some compensatory clause for tenant's investments) may possibly reduce his security of rent and property (2). In effect, according to the "perfect" lease requirement the landlord has to share in the variable costs incurred by the farm enterprise and consequently would be much more dependent on the tenant's ability and integrity than under the customary crop-share lease. This also applies to the tenant with regard to the landlord.

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[1]Perfect under the assumptions of this analysis. This does not mean that in all circumstances it is the best.

However, all the above does not obscure the merits of the "perfect" lease concept as an analytical tool in economics. It is not only a model or norm to which all leases should tend to imitate, at least, in some of their aspects, but also is a standard against which all leasing systems can be evaluated at least in bulk, i.e., in an unquantified way.

2. Share-crop leases and cash leases

A certain deal of controversy has been underway the past years related to the relative advantages of crop-share and cash leases. The supporters of the latter contend that cash leases automatically fulfill at least the first two incentive conditions whereas crop-share leases, as has been empirically established by Hurlburt and others, are far from meeting all the requirements of the "perfect" lease (13, 19, 23, 31).

Others argue, saying that even if cash-leases do fulfill the first two conditions they present other disadvantages. In particular, they may violate the third condition: the cash rental payment may not correspond to the marginal productivity of land. Furthermore, cash leases may produce more risk and uncertainty of the future. Contrariwise to crop-share farming, the commitment of a large and fixed rent remains unaltered, even in the case of poor yields.

Another disadvantage of cash leases lies in the fact that they tend to encourage the depletion of the soil fertility. The landlord, in case of better crops, does not get any part of the increased yields. The tenant is thus encouraged to deplete the farm without caring about the future consequences for his successor. In this case there is a violation of the fourth condition.

The question about the relative merits of share and cash leases is difficult to settle. Undoubtedly, there are advantages and disadvantages associated with the two types of leases. Perhaps both of them could be advocated according to the types of farming, geographical situation, expectations for the future and many other factors. This is hardly the positions of certain authors who deny that the "perfect" lease, as understood by Heady, is possible. Their argument is that sharing costs in the same way as the product tends to create at most an imperfect partnership, which is not adapted to the aspirations and abilities of most landlords and tenants (2, p. 6).

This line of thought has some basis for its support as seen above. However, the fact that the livestock lease, also very much akin to a partnership, is quite widespread in many regions invalidates the universality of the objection. If there are farmers and tenants willing to join resources in a livestock-share lease, it is also possible to conceive that the "perfect" lease could be implemented on cash-grain farms. The main difficulty lies in the removal of defective customary arrangements which, as many other institutional forces, may have an adverse effect on economic efficiency.

D. Certain Dynamic Implications of the Incentive Conditions

1. Condition three and the basis of sharing

Perhaps it has not been stressed sufficiently that condition three also applies to the fixed contributions of the landlord, i.e., land and buildings, and the tenant, i.e., labor and machinery.[1] The fixed resources contributed by both parties should determine the basis of sharing used in the lease, and not, as is frequently done, the traditional ratio which is customary in the area. Take as an example the 50-50 share of crops so widespread in the Midwest. Up to what extent is it justified? It may have been equitable some time in the past but this does not assure that today it is adjusted to the value of the land, machinery and labor. The relative prices of those factors of production may change through time thus demanding a constant readjustment of the basis of sharing between landlord and tenant.

A periodical valuation of their resources and a negotiation on the proportion of returns going to each party is required. The ratio of the landlord's and tenant's fixed contribution to the contract should determine the ratio of sharing, which need not necessarily be 50-50 or any other specific ratio.

Undoubtedly, this would bring about some problems of valuation (20). Some conflicts between lessee and lessor may arise during the bargaining process as it has been suggested by some authors (18). But once an agreement is reached, this would provide more incentive to farm in an efficient way since the arrangement should be satisfactory to both parties. In this field of fixed resources, there is need, undoubtedly, for more research.

2. <u>The fourth incentive condition: an example</u>

It is necessary to proceed further in the analysis of the fourth

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[1]The farm is under a crop-share lease. Note that labor is considered as a fixed resource.

condition, since it constitutes the core of this research. A hypothetical example will be used for this purpose. Suppose a tenant who would like to use some conservation practices such as terracing. The landlord, however, does not want to bear all the costs of them, which are $7.00 per acre payable on year t=0.[1] They finally agree on sharing costs on a 50-50 basis, since the crops are shared in the same way. The increase in yield, due to terracing, per acre of continuous corn is assumed to be 3 bushels and the price of corn $1.10 per bushel. The terraces are supposed to last 10 years and do not need any maintenance expense. Table 3 shows the present capitalized values of added yearly returns and the respective shares going to landlord and tenant. The present capitalized value of the yearly cost is also presented.[2]

Now assume that the tenant has only a 5 year contract without compensation provisions and therefore a guaranteed planning horizon of only five years. However, the optimum planning horizon has a length of 10 years.[3]

The tenant is encountered with one of three alternatives. If the lease contains no compensation clause for investments yielding returns beyond the tenant's planning horizon, there will be a dissociation of benefits and costs. The tenant will not receive the expected added returns of the last five years. The present capitalized value of these

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[1]The Federal Government bears 70% of the costs.

[2]An interest rate of 5% is assumed.

[3]After the tenth year, the returns added every year become zero thus setting the lower limit of the optimum planning horizon.

Table 3. Capitalized value of added returns per acre resulting from investment in terracing.

Year	Yield differential bu. per acre	Capitalized value of yearly costs $ per acre	Added returns $ per acre	Capitalized value of added returns $ per acre	Capitalized value of shares of added returns $ per acre
0	3	.35	3.30	3.30	1.65
1	3	.35	3.30	3.14	1.57
2	3	.35	3.30	2.99	1.50
3	3	.35	3.30	2.85	1.42
4	3	.35	3.30	2.71	1.36
5	3	.35	3.30	2.58	1.29
6	3	.35	3.30	2.46	1.23
7	3	.35	3.30	2.34	1.17
8	3	.35	3.30	2.23	1.12
9	3	.35	3.30	2.13	1.06
10	0	0.00	0	0	0

expected returns is $5.87 per acre and it is represented in Figure 1-A by the shaded area.

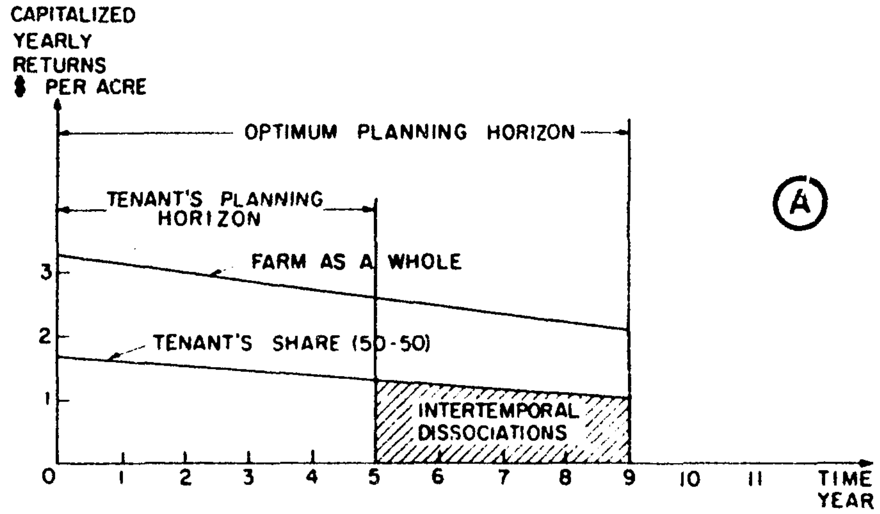
The second possibility is that the lease contains a compensation clause for unexhausted investments. But it only covers the costs of those investments. From years 6 through 10, the capitalized value of yearly costs amounts to $1.75 per acre. The capitalized value of the yearly additional returns is $5.87 per acre. Evidently this type of compensatory clause does not suppress all inefficiencies because there is still a dissociation of benefits and costs in the person of the tenant. The landlord receives returns from resources which he did not contribute. This amounts to $4.12 per acre of capitalized value as shown in Figure 1-B. Consequently, the tenant is still not fully stimulated to make that investment.

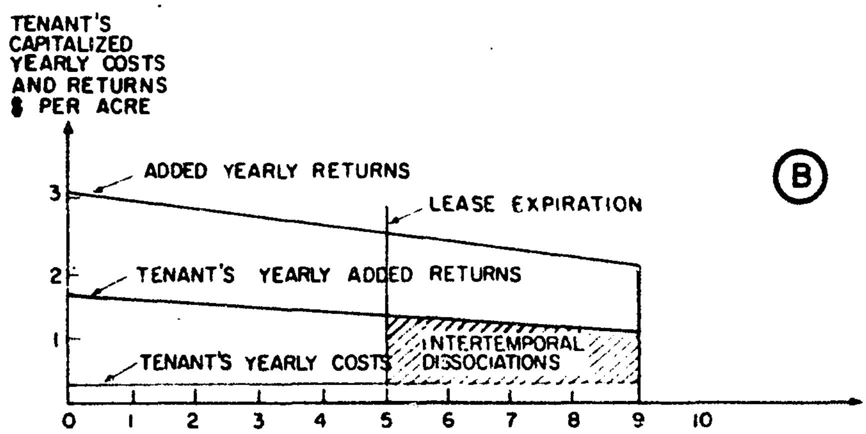
Finally, the third possibility open to the tenant and the one in full agreement with the fourth incentive condition, is that the tenant be compensated for the potential earnings of his inexhausted investments. In this case, there is a perfect association of benefits and costs since the tenant receives all the returns attributable to each unit of resource. He will be, with regard to incentives to invest, on an equal standing with the landlord and the owner-operator.

3. <u>The second incentive condition: a qualification</u>

The incentive conditions have been generally used in a static framework. It is then pertinent to ask whether, if transposed to a dynamic framework, they could be useful or not. It looks obvious that the first and third condition dealing with intra-temporal efficiency are unaltered

Figure 1. Inter-temporal dissociations in leases with no compensatory clause and with compensatory clause for unexhausted investments


CAPITALIZED
YEARLY
RETURNS
$ PER ACRE
OPTIMUM PLANNING HORIZON
TENANT'S PLANNING HORIZON
A
FARM AS A WHOLE
TENANT'S SHARE (50-50)
INTERTEMPORAL DISSOCIATIONS
0
1
2
3
4
5
6
7
8
9
10
11
TIME YEAR


TENANT'S
CAPITALIZED
YEARLY COSTS
AND RETURNS
$ PER ACRE
ADDED YEARLY RETURNS
B
LEASE EXPIRATION
TENANT'S YEARLY ADDED RETURNS
INTERTEMPORAL DISSOCIATIONS
TENANT'S YEARLY COSTS
0
1
2
3
4
5
6
7
8
9
10

if time is brought into the picture.

Condition four, being nothing but an explicit extension of condition three over time, is most appropriate in dynamic analysis. The only one remaining is condition two which states that the share of all products between landlord and tenant must be the same. This means, in dynamic terms, that not only all products should be shared on an equal proportion on year t=0 but also through year n , until the lease expires.

This might sound as a truism. However, if all products are shared in the same proportion, this does not mean that the proportion of them going to tenant and landlord must remain unchanged until the expiration of the contract. It could change every year, provided that within each year, all the products be shared on the same basis. This, conceivably, could have some importance. In effect, one of the social functions of leases is to help beginning farmers to get started. It has been argued that it is not very effective nowadays in the United States because technological progress requires from farmers an enlarged investment on machinery and equipment. It is therefore very difficult for young operators with low equity to establish themselves on a farm. For that reason, leases with flexible and adjustable sharing proportion between landlord and tenant have been advocated (18).

Suppose that the first year the landlord and tenant share on a 65-35 basis, the following year on a 60-40 basis and finally, as the tenant's capital is building up, and is re-invested in machinery (crop-share lease) or livestock (livestock-share lease), the sharing ratio between lessor and lessee could tend toward the 50-50 ratio.[1] Of course, other alternatives besides leases with adjustable sharing proportions are possible. For instance, beginners could start renting small farms and as their net worth increases, they could rent additional tracts of land in the vicinity, or, even move to larger farms.

E. The Method of Inquiry and Its Relation to Theory

At this point it becomes relevant to evaluate the theory of leasing in relation to the purposes of this study. This theory has provided us with a norm or standard of efficiency. Attention can now be turned to the actual situation. Customary leases fall short of the norm or standard. The presence of a gap can be detected by investigating whether or not the different leases meet the four incentive conditions. The answers given by several empirical and mostly descriptive studies are clear (2, 19, 29). Most of the customary leases violate one or more of the incentive conditions. These empirical studies, however, give an answer in bulk rather than in precise terms. These studies do not measure in quantitative terms the gap due to lease engendered inefficiencies; they rather indicate its existence.

1. Leasing systems and single equation models

Others have endeavored to measure those inefficiencies by resorting to productivity analysis. Single equation models are used to determine the over-all efficiency of existing leasing arrangements and also relative

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[1]Assuming that the basis of sharing is the equitable one under the specific circumstances surrounding the lease studied.

efficiencies. A measure of the latter is obtained by deriving production functions for groups of farms which have common tenure characteristics. These functions can then be tested to detect significant differences in productivity between groups. If any significant difference between two groups of tenure is found, it is inferred that there are tenure factors engendering inefficiencies in resource allocation.

However, the single equation models employed to estimate tenure parameters have serious shortcomings. It is impossible to derive from empirical data a production function corresponding exactly to the production function provided by economic theory. There are several reasons. The aggregation of inputs and outputs presents a serious problem (26). Likewise, the non-inclusion of certain variables like management into the production function may cause a severe upward bias in the capital input elasticity (7). The reason is that capital and managerial ability may be highly correlated in the agricultural firm. The failure to introduce quality differentials in the labor input may produce downward biases in the latter's elasticity. Furthermore, the fact that inter-firm data is used to provide an intra-firm function questions the validity of recommendations for farm management and policy based on production functions like the Cobb-Douglas function (3, 25).

It is true that the heterogeneity of farm samples could be somewhat reduced by careful sampling (23). Also, the management problem could be decreased by selecting a sample of farms which show similar managerial inputs or by the introduction of a management index. Likewise, inputs and outputs could be carefully aggregated. But as long as the above improvements are not developed, Cobb-Douglas results should be accepted with extreme caution.[1] As of now, these results give some clues about the specific effect of leasing structures on resource allocation rather than precise answers.

2. Leasing systems research and linear programming

The introduction of linear programming into tenure research may be due to the limitations found in the value product analysis. As stated before, these two techniques are not substitutes for each other but rather they are supplementary. The main difference is that linear program is applied to individual cases and has a normative character whereas production functions attempt to give an over-all efficiency estimate of actual farming situations.

Is it possible for linear programming to provide precise answers to the question of lease-engendered inefficiencies? Economic theory supplies a norm which should be followed, i.e., that the optimum plan for the tenant and the landlord should be the same and that those two plans should be the same as that for the farm as a whole. The owner-operated farm becomes then the norm for testing other tenure arrangements. The reason is that the owner provides the resources and obtains the returns thereof. There is perfect association of benefits and costs in his person. However, the owner-operator must be debt-free because if he bears a heavy encumbrance he even could be less efficient than a tenant with adequate

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[1]All along it has been assumed that statistical problems associated with the derivation of production functions have been conveniently solved (34, Chapter V).

capital availability.

The "perfect" leasing arrangement which permits all profits to be associated with costs should also be as efficient as owner-operatorship. There are only two ways in which leasing arrangements can affect the level of profits of the optimum plan. One is through the technical coefficients of production, prices and resource restrictions which belong to a particular farm situation. The other is through cost and income arrangements which affect the revenue received by lessor and lessee.

However, input-output coefficients, prices and resource restrictions can be maintained at the same fixed level while programming the owner-operator and "perfect" lease plans.[1] Then, under the usual assumptions, there is no theoretical reason to expect that the optimum plan for the owner-operator should not be the same as that for a farm under a "perfect" leasing arrangement, i.e., one which meets all the incentive conditions.

Having obtained the norm, a farm can then be programmed under different tenure arrangements. If the level of profits is different between the two plans, the difference can be attributed *per se* to leasing arrangements. There are two types of lease-engendered inefficiencies: those caused by intra-temporal and those of inter-temporal dissociations.

Intra-temporal inefficiencies can be isolated by programming a farm, within one period of time, under the customary sharing agreements of any lease type. Then the optimum plan is compared to the owner-operator's optimum plan or to the "perfect" lease plan. In both cases static linear

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[1]It will be seen below that this is not possible for crop-share rented farms in the case of the capital resource.

is used.

Inter-temporal inefficiencies in resource allocation are detected in a similar way. First, the optimum enterprise combination is obtained by using dynamic programming for a certain number of years. The length of period chosen, i.e., the number of years, is assumed to be adequate in the sense that it would assure perfect association of costs and benefits in the person of the tenant. This first plan is for a farm operated under a "perfect" leasing arrangement.

Second, the farm is programmed for the same number of years but now under the sharing provisions of the leasing system which is investigated. If there is a difference in profits between the renter's plan and the "perfect lease" plan, this difference is attributed to intra-temporal inefficiencies. The difference is the sum of the inefficiencies within each discrete period of time.

Third, in order to trace the malallocation of resources engendered by a lease through time, a series of consecutive plans, covering the same period of years as the long-run plan under a "perfect" leasing arrangement or norm, must be programmed. These consecutive plans are for a tenant under a "perfect" intra-temporal leasing arrangement but under a relatively short planning horizon. This means that the lease fulfills conditions one to three but that it violates condition four. By comparing the long-term plan with adequate planning horizon, the norm, with the consecutive series of plans with inadequate planning horizon, inter-temporal inefficiencies in resource allocation due <u>per se</u> to leasing systems are isolated. If there are such inefficiencies, the norm and the set of short-term plans will lead to a different combination of enterprises over time and profits of the first will be greater than the sum of profits of the short-term plans.

Evidently, also inter-temporal inefficiencies due to leasing systems could be found by running another series of consecutive plans for tenants with limited planning horizon and under customary leasing arrangements. The difference in profits between the long-term share-rented farm plan under customary arrangements and these plans could be attributed *per se* to inter-temporal lease-engendered inefficiencies. This study will mostly follow this last procedure to detect inter-temporal inefficiencies.

It is important to emphasize here that the norm used in this study is no more the owner-operator's long term plan but rather the crop-share renter's long term farm plan. This is a departure from previous empirical studies using linear programming (6, 13). The reason is that in a dynamic framework it is not possible to set the owner-operator's and the crop-share renter's plans at the same level of capital. Consequently those two plans cannot be compared in order to detect inefficiencies due *per se* to the leasing arrangement.

In the first year the owner-operator's level of capital can, of course, be equal to the sum of the landlord and tenant capital on a share-rented farm. The allocation of that capital will take a different form in the two cases, however. In effect, the crop-share renter is not free as the owner-operator to use the total amount of capital available to him, i.e., his part and that contributed by the landlord, in any way he wants. The landlord's capital is only available for investment in crop activities and not in livestock activities.[1]

If the rate of return from crop and livestock activities is different the first year capital resources will be allocated differently on an owner-operated farm and on a crop-share rented farm. Hence, the returns at the end of the year will be different in the two cases. Since these returns or a part thereof become the capital input for the second year the capital available in the second year, and in later years, is going to differ in an owner-operated farm and a crop-share farm. It can be concluded that optima dynamic plans for an owner-operator and a crop-share rented farm cannot be usefully compared in measuring inter-temporal inefficiencies due to crop-share leasing arrangements.[2]

3. Interpretation of results from linear programming

In answer to the question posed at the beginning of the previous section it can now be said in theory, linear programming can give a satisfactory measure of malallocation of resources caused per se by leasing systems. In this sense, linear programming offers advantages over production functions. However, it is important to keep in mind that the linear programming technique is constrained by its very nature to give results which are not universal in its extension. They apply to particular situations and do not give more general measurements of inefficiencies as

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[1] In reality all crop-share leases violate the second incentive condition which says that the share of all products between landlord and tenant must be the same. The livestock activities are shared on a different basis than the crop activities in customary crop-share arrangements in the Middlewest.

[2] This is not the case of a livestock lease in which both crop and livestock activities costs and returns are shared by landlord and tenant.

production function attempts to do.

For instance, the reduction in landlord and tenant income which is the measure of the inefficiency of a particular leasing arrangement has the following interpretation: It applies only to farms which have a specific amount and type of resources, with a certain type of management; it is restricted to a particular set of technical coefficients of production; it is also dependent on the price relationships used, i.e., on the expectation model assumed for the farmer.

Evidently, if all these factors kept constant, while obtaining a certain optimum, are permitted to vary, the results obtained could also vary considerably.

It is true that certain refinements can be introduced into the technique in order to use variable prices for some activities and also variable levels of certain resources, but this does not essentially alter the fact that linear programming deals with particular situations.

To obtain a more general measure of efficiency by this method, a very extended research covering most of the typical farm situations in different soil areas would be necessary. This implies the availability of great amounts of research funds. Given the present computational techniques and the costs of research, the possibilities of a large scale project of that type do not look very bright.

It can be concluded that linear programming is a very useful technique in land tenure research. It can provide a measure of efficiency, which, although applied only to particular cases, nevertheless is more satisfactory with regard to reliability of results than other known techniques.

It is in the area of inter-temporal inefficiencies due *per se* to leasing systems where the dynamic programming technique can be applied to great advantage. The reason is that there is a considerable gap in research. Dynamic programming has been applied to management and household planning rather than to tenure problems (24, 28). It is precisely the purpose of this inquiry to make an empirical study of the inter-temporal inefficiencies in leasing arrangements.

F. Hypotheses Guiding This Study

The above presentation of the theory of leasing in its relation to dynamic linear programming had the following purpose: to provide us with the necessary elements to formulate the theoretical hypotheses which will guide the empirical research.

1. Inadequate planning horizon engendering uncertainty of tenure, caused by short-term leasing arrangements, produce an inefficient inter-temporal resource allocation and affect the nature of profitable investment. Inefficiency is revealed through a lower level of returns for the firm under short-term customary leasing arrangements than the one attainable under the same leasing arrangements but with adequate planning horizon for the tenant.

2. Short-term leases affect the rate of the investment of the tenant in fertilizer and lime, buildings and equipment, and conservation practices. Uncertainty of tenure may also produce malallocation of resources by limiting the number of enterprises eligible for the tenant.

3. Capital resources have an important role in the inter-temporal allocation of resources. The relationships between the restrictions in the amount of landlord's and tenant's capital and the sharing of costs and returns have also an impact on the rate of investment of the tenant in fertilizer, buildings and equipment, and in the use of terracing.

4. In a lease characterized by customary sharing of benefits and costs an increase in efficiency could be obtained by: (a) adequate planning horizon assured by longer-term leases or in its defect by provisions of compensatory payments to the tenant according to the earning power of his unexhausted resources, in case of short-term leases or cessation of contract; (b) modification in the quantity of capital contributed by the landlord and tenant; (c) modification, in the quantity of resources contributed by the two parties and in the sharing of products between them.

III. FORMULATION OF A MODEL

A. The Dynamic Linear Programming Technique

In the last few years empirical studies have been made to determine optima farm plans over a period of years (23,27). These plans have restrictions imposed by limited availability of fixed and variable resources and a yearly allowance for household consumption of the operator and his family. Capital available in a limited amount the first year is permitted to grow in subsequent years by reinvesting in the firm the annual returns. In a similar way, outputs of certain activities in a year become inputs in the following year. Thus, activities in each of the total number of years covered by the plan are interrelated.

1. Dynamic linear programming

The technique called dynamic linear programming allows maximizing the returns (or any other choice criterion) from activities or enterprises for k discrete period of years ($k = 0,1, \ldots, t$) subject to restrictions in the availability of resources in all the k years (1, 5, 32).[1]

$$f(X) = c' \cdot x = \max. \qquad (1)$$

Let $f(X)$ be the objective function which is maximized. It may represent gross returns, output or net returns of a firm. The element c_{jk} of the column vector of order n is the present discounted value of c_{jk}, the price or return of the j^{th} activity in the k^{th} year, and x_{jk} of the program

[1]The usual assumptions of static linear programming hold also for dynamic programming: linearity (production coefficients are constant; additivity (no interaction between different resources); finiteness (number of activities is not infinite); and, divisibility of inputs and outputs.

or activity vector x of order n is the level of the j^{th} economic activity in the k^{th} year.

$$A \cdot x \leq b \qquad (2)$$

The matrix of inequalities A of order m x n is composed of the fixed input-output coefficients. Its element a_{ijk} has three subscripts.

The subscript i denotes the i^{th} restriction or row (i=1,2,...,m); the subscript j symbolizes the j^{th} activity (j = 1,2,...,t).

The element b_{ik} of the column vector b of order m represents the quantity available of the i^{th} resource in the k^{th} year.

Each economic restriction is obviously subject to the condition of non-negativity:

$$x \geq 0 \qquad (3)$$

In order to get rid of the m inequalities a column vector y of m components or slack variables is introduced. The inequalities are thus transformed into equalities.

Let z be a new activity vector of order m + n:

$$z = \begin{bmatrix} x \\ y \end{bmatrix} \qquad (4)$$

and B a new matrix of order m (m + n)

$$B = \begin{bmatrix} A \ I \end{bmatrix} \qquad (5)$$

where I is the unit matrix of order mxm.

A new vector d is also defined:

$$d = \begin{bmatrix} c \\ 0 \end{bmatrix} \qquad (6)$$

where 0 is a column vector of m components corresponding to the slack variables. These m components are all zero.

a new objective function is maximized:

$$g(Z) = d' \cdot z = \max. \tag{7}$$

under the restrictions imposed by the resource availability

$$B \cdot z = b \tag{8}$$

and the non-negativity condition for economic activities

$$z \geq 0 \tag{9}$$

Apparently this model does not differ from the standard static model of linear programming. The difference lies in the interpretation of the column vector c. Its n components are no longer the prices or returns from the n activities of one period of time but rather the present value of discounted prices or returns of all the k years included in the plan. Therefore, this model makes use of comparative statics or dynamics in the Hicksian sense.

Hicks assumes that the entrepreneur makes a production plan for t periods, that inputs and outputs of different periods are altogether different inputs and outputs, that the technological coefficients may change from year to year and also that prices of inputs and outputs may change. The latter assumption has the qualification that the entrepreneur has single-valued expectations discounted for uncertainty. All the above assumptions can be incorporated into the dynamic model of linear programming.[1]

The ends-in-view of the farmer over time and the possible means of

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[1]We must not forget, of course, that linear programming is not dealing with continuous production functions and that it assumes constant returns to scale.

observing them will be considered. It will then become possible to build a reasonably realistic model which takes account of these two factors.

B. The Agricultural Firm Over Time: Ends and Means

1. Ends-in-view of the farmer

Let us consider an agricultural firm such as an owner-operated or a leased farm. It can be assumed that the farmer and his family live on the farm. Under these circumstances the farmer has two main long term ends-in-view: the increasement of his net worth over time, and a guaranteed minimum level of annual family consumption.[1] These two goals are related in a competitive way. Figure 2 shows a transformation curve for a fixed level of resources. The vertical axis indicates the units of resources diverted for family living and the horizontal axis the units of resources used in the production process.

Family living is considered to have precedence, up to a specified limit, over increase in the farmer's net worth. A minimum of consumption is needed for the survival of the farmer and his family. Therefore, production will never divert resources from consumption beyond the point of minimal consumption. At that point the rate of substitution of consumption for production in the farmer's preference becomes infinity. This is shown in Figure 2 by the shape of the series of indifference curves IC. They approach asymptotically a line indicating the minimum level of consumption.

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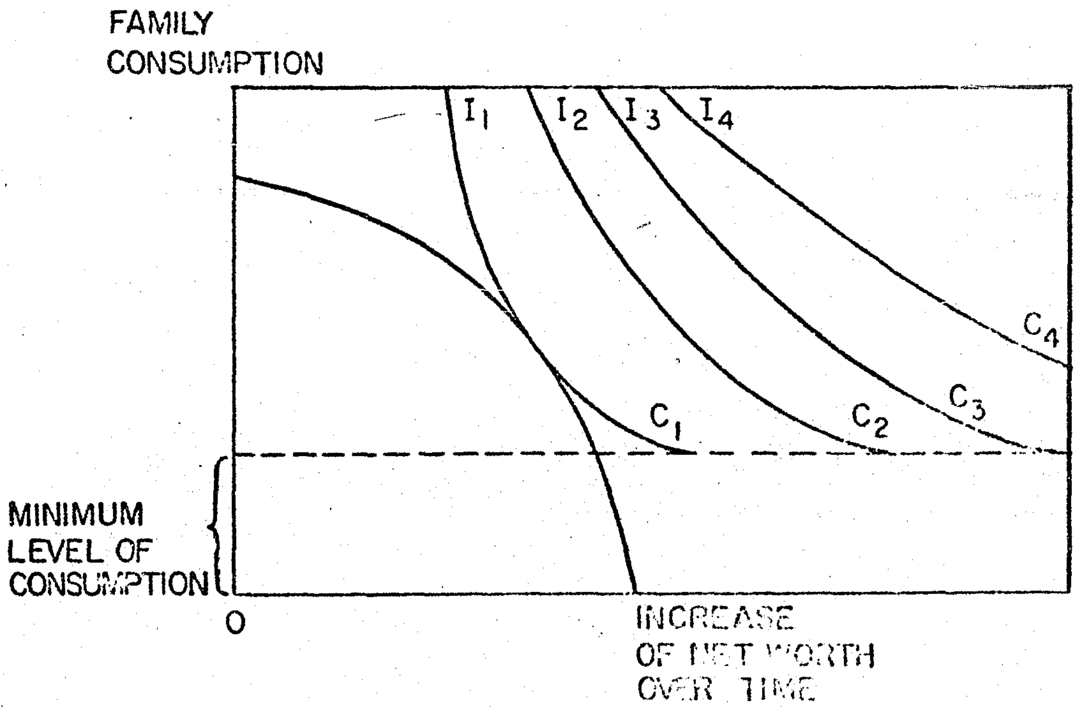
[1] Other long term goals could be considered such as additional leisure. However, this study will be restricted to these two goals which seem reasonable.

Figure 2. Ends-in-view of the farmer over time


FAMILY
CONSUMPTION
I_1
I_2
I_3
I_4
C_1
C_2
C_3
C_4
MINIMUM
LEVEL OF
CONSUMPTION
0
INCREASE
OF NET WORTH
OVER TIME

Above the minimum level of consumption, consumption and production compete for the available resources. It is assumed that the preferences of the farmer are a function of the level of annual income. The shape of the indifference curves IC hypothesizes that as income increases the farmer prefers to divert relatively more resources from production.

2. <u>Means to achieve the ends-in-view</u>

There are means open to the farmer to achieve the two ends he seeks. In order to transform inputs into outputs he needs to acquire control of resources. This may be by one of three ways: by reinvesting his net worth; by borrowing capital; or by pooling his own resources with other persons. Leasing arrangements are an example of the latter.

However, another means is also available to the farmer to achieve his objectives. This may be by investing not in his farm but in external enterprises. For instance, the farmer can invest in stockshares, bonds, savings accounts, or in any business enterprise.

Consequently, the entrepreneur after having met his consumption preferences each year may invest part of his returns in the farm and part in some external investment.

Perhaps the previous ideas can be expressed better by means of a single diagram as in Figure 3A. It represents the decision-making unit in the year k=0. The farmer has a given amount of resources coming from the three sources mentioned above. The resources in the year k=0 are channelled according to the preferences of the entrepreneur into three directions: family consumption, reinvestment in the farm and external investment.

The situation in year k=1 is somewhat different as shown in Figure 3 B. There are now four sources or ways of acquiring control over resources: 1) from previous year's returns of the farm enterprise; 2) from returns of external investment; 3) from borrowed money; and 4) by pooling resources with a second party in a leasing arrangement or partnership.

Again the entrepreneur controlling a bundle of resources will have to make a choice between consumption and investment in the farm or in an external enterprise. As annual income increases it may happen that family consumption increases above the minimum needed for the necessities of life. Therefore, more resources may be diverted from production for family consumption in year 1 than in year 0.

C. A General Dynamic Model of an Agricultural Firm

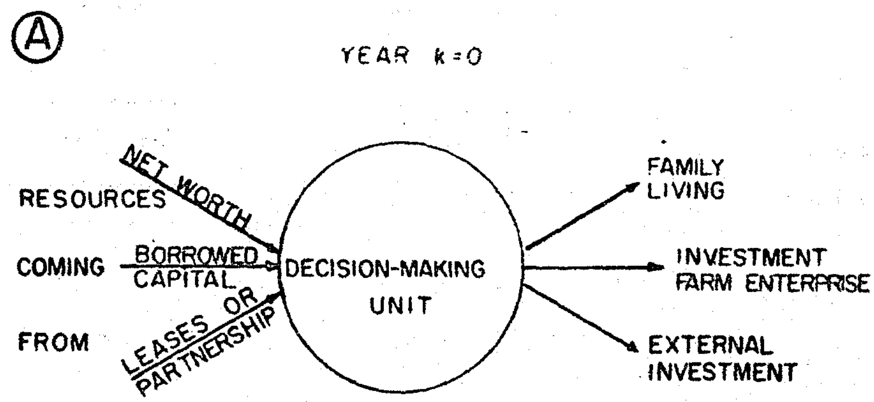
Having stated above the ends-in-view over time of farmers and the means to implement them, the question arises of how these ends and means can be expressed in a programming model. From the nature of linear programming it is known that ends are expressed in the objective function and means by the different economic activities.

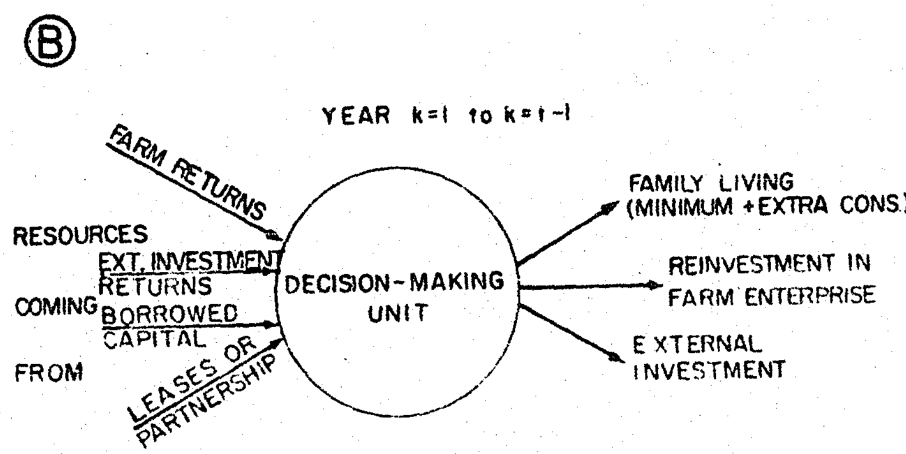
1. The objective function

When the static linear programming is applied to agricultural problems it usually maximizes net returns in money terms. That is, the components of the vector d in (7) are the net prices of activities or the difference between total returns obtained from a unit of activity and variable capital expense per unit of activity.

It is convenient to examine the significance of maximization of net returns. These are defined as:

Figure 3. Allocation of resources in year 0 and 1 in an agricultural firm


A
YEAR k=0
RESOURCES
COMING
FROM
NET WORTH
BORROWED CAPITAL
LEASES OR PARTNERSHIP
DECISION-MAKING UNIT
FAMILY LIVING
INVESTMENT FARM ENTERPRISE
EXTERNAL INVESTMENT


B
YEAR k=1 to k=t-1
FARM RETURNS
RESOURCES
COMING
FROM
EXT. INVESTMENT RETURNS
BORROWED CAPITAL
LEASES OR PARTNERSHIP
DECISION-MAKING UNIT
FAMILY LIVING (MINIMUM + EXTRA CONS.)
REINVESTMENT IN FARM ENTERPRISE
EXTERNAL INVESTMENT

$$N.R. = T.R. - T.C. \tag{10}$$

where T.R. is total returns and T.C. total costs.

If the right hand side of equality (9) is examined, it can be seen that net returns in the linear programming context have a different meaning than in economic theory. In effect T.R. are attributable to all fixed and variable resources which a firm transforms into output. However, T.C. consists only of yearly cash outlay. In the linear programming approach T.C. evidently excludes all costs originating from resources other than capital such as labor, management and fixed resources.

It can then be concluded that in the standard programming approach maximization of "net returns" is rather misleading because only cash costs are accounted for. All other resources, fixed and variable, are taken as given and they constitute the restrictions under which net returns are maximized. Therefore, "net returns" in that context is a misnomer. It should rather be "net returns above variable capital expense."

It could be argued that a matter of names is not very important if the idea behind the names is correct. However, for our purposes, neither the concept or the terminology is quite correct. The ends to be maximized in this model are the increase of net worth of the farmer, allowing for a satisfactory family consumption. Maximization of discounted annual net returns is not completely consistent with those ends.[1]

In effect, a farmer having those ends-in-view when planning for the

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[1]We will see later, however, that under certain conditions the optimum feasible solution for programs maximizing net returns and gross returns allows for the same allocation of resources.

future will not be concerned with maximizing the net returns of every year included in the plan. What he wants to emphasize is growth of his net worth over time. Therefore, after providing for family consumption, he will rather maximize his capital resources available at the end of the terminal planning year. That is, he will maximize total money returns of year k=t.

Therefore, the objective function is as (7)

$$g(Z) = d' . z$$

subject as before to conditions (8) and (9), where g(Z) is now total money returns of the firm. The element d_{jk}, of the vector d is the present capitalized value of $\bar{d}_{jk}$, the expected gross return in money terms or expected market price of the j^{th} activity in the k^{th} year.

There are additional conditions to meet in this model. Only total returns of the last year, t, are maximized, because prices of all activities in any year k=t are equal to zero. In matrix notation:

$$d_{jk} = 0 \text{ , } k = t \tag{11}$$

and

$$d_{jk} \geq 0 \text{ , } k = t \tag{12}$$

The advantages brought by this objective function over the standard one used in other studies are twofold. First, it avoids the pitfall of using the name "net returns" in an equivocal sense. Second, it conforms with the ends-in-view sought by agricultural entrepreneurs over time.

Our model departs from Hicks in that his entrepreneur maximizes net returns of every year whereas our farmer maximizes gross returns of the terminal year of his plan. Our model is better adapted to meet the goals of an agricultural firm, more precisely of an owner-operated or rented farm.

If closer look is taken at the objectives sought by the Hicksian entrepreneur a further difference is found. Hicks' entrepreneur maximizes the income surpluses over time, but that income is not reinvested in the firm or in an exterior concern. This shows that Hicks analysis is reduced to only the first of the three alternatives shown in Figure 3.

Our model also differs from the Heady models (23, 27) in that his farmer has only two choices open to him: he can consume part of the income surpluses and the rest has to be forcedly reinvested in the farm. In terms of Figure 3 it can be seen that these models make use of the first two alternatives. No exterior investment is considered in these models. Our model brings more flexibility by permitting more alternatives. The goals sought by our farmer, that is, the increase of his net worth over time after having met the minimal family consumption, appear more realistic than the goals in the Heady model. It is more difficult to conceive a farmer planning for the future maximizing net returns each year and less concerned with the increase of his capital resources.

In reality the two objective functions, net returns and total returns of the terminal year of the planning period, represent a choice between the immediate versus the future. In some cases this choice has no particular impact on allocation of farm resources. In effect, if the internal rate of growth of the firm is greater than the external rate of growth, i.e., represented by the rate of interest obtained by bonds or the rate of returns from exterior enterprises, then maximization of returns from activities of each year included in the plan becomes complementary with maximization of the returns of the terminal year. But also maximization of the alternative objective functions may become competitive and then the allocation of resources will be different when maximizing each function. This may happen when the external rate of growth (of capital) is greater than the internal rate of growth.[1] Then allocating resources in order to maximize returns in the first years of a long-term plan will decrease the returns of the last years and vice-versa.

The difference between the two objective functions can be illustrated algebraically. Let the left hand side of (13) be the sum of net returns of a two-year plan[2] and the right hand side the total returns of the last year:

$$\sum(X_{i1}R_{i1}) - \sum(X_{i1}C_{i1}) + \sum(X_{i2}R_{i2})\beta - \sum(X_{i2}C_{i2})\beta \gtreqless \sum(X_{i2}R_{i2}) \qquad (13)$$

where X_{ik} is the level of the i^{th} activity in the k^{th} year, R_{ik} is the market price of the product of the i^{th} activity in the k^{th} year, C_{ik} is the capital requirement of the i^{th} activity in the k^{th} year and β is the discount factor in the k^{th} year.

In order that the left hand and right hand side of (13) becomes an equality by maximizing them, two conditions have to be met.

First, the capital available in year 1 must be a fixed amount and nothing of it can be left unused or in disposal in the optimum plan:

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[1] When we talk of the external rate of growth and the internal rate of growth we mean expected rates of growth. Evidently, the external rate of growth is expressed through the discount factor β used in obtaining the present value of returns. Likewise it is expressed by the rate of return of the capital selling activities.

[2] This reasoning can be extended to any number of years.

$$\sum(X_{i1}C_{i1}) = K \tag{14}$$

Second, the discount factor β must approach one, that is, the interest rate for external investment must be low.

If these two conditions are met and since total returns of one year are equivalent to the capital supply of the following year, (13) becomes:

$$\sum(X_{i1}R_{i1}(1 - \beta\ ) - K + \sum(X_{i2}R_{i2}) = \sum(X_{i2}R_{i2}) \tag{15}$$

where the first term becomes zero as β tends to 1. Under these conditions maximizing the sum of discounted net returns and maximizing discounted total returns of the last year, i.e., taking the derivative of (15), produces the same allocation of resources in the optimal plans for the two different objective functions.

What evidently differs in maximizing the two alternative objective rows is the level of returns of the optimal feasible solution. Gross returns of the last year could only by chance be equal to the sum of net returns of the t years included in the plan.

It is important to remark here that if the two conditions stated above are met, the optimal plan maximizing total returns of the terminal planning year is an efficient one. That is, the results obtained by linear programming are consistent with the equilibrium conditions for the firm as given by economic theory (6, chapters 7 and 8.

This means that if the feasible activity or program vector z of (4) satisfies all restrictions in (8) and (9) and maximizes function g(Z) of (7), then we call that a feasible optimum program. That optimal feasible solution will bring about an allocation of resources whose relation to a given set of prices is consistent with that of a profit-maximizing firm meeting the necessary and sufficient conditions for equilibrium.

2. Economic activities and restrictions

In programming language the means of implementing the objectives sought by the entrepreneur are expressed through the n "activities" or "processes". An activity could be loosely defined as "a way of doing things". The basic idea behind the concept of activity is that there are different manners, i.e., different composition of inputs, to obtain the same results.

For instance, a farmer may use more or less seed per acre in growing a crop. This would represent two different activities. But if using the same amount of seed per acre he plants twice as much area as before, it is the same activity but used at a different level.[1]

Activities are not only confined to physical operations. They may be purchasing, selling, borrowing activities as well as "artificial" activities. The latter are used for special purposes such as the fulfillment of the family living restriction.

The availability of inputs is expressed by the resource restriction vector b as in (2) that represents the supply level of different resources. Here again, the restrictions are not confined to physical resources but also may include financial, institutional and other types of restrictions.

In our model the entrepreneur has three channels towards which and

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[1]Here we encounter the familiar assumptions of constant returns to scale, additivity and divisibility of inputs and outputs. They may be somewhat embarrassing at times.

according to his preferences, the resources can be allocated. These are family consumption, investment in the farm and investment outside the farm. The details of how this activity operates are given in the models presented below.

3. A numerical illustration

The main characteristics of the dynamic programming technique can be better understood by considering the contrasts between models using different objectives functions and different sets of activities. The farm situation presented below is an over-simplification of reality and its only purpose is to serve as example of the models. The resource supplies or restrictions and the activities common to all models are summarized in Table 4. Summary of a farm situation for different models.

Restraints affecting the operator	Production alternatives open to the operator
200 tillable acres of land	livestock activities:
\$9000 of operating capital	2-litter hog enterprise
30 units of hog space and managerial ability for production 30 hog units	crop activities:
	C-C-C
1072 hours of labor	C-C-O-M-M
\$4500 of fixed costs (family living plus depreciation and taxes)	C-Sb-O-M-M
	other activities:
	Corn buying
	Corn selling

In table 5 a brief summary of the characteristics proper to each model is presented. Each model covers a period of three years.

Table 5. Special features of each model

Model	Objective function maximized	Special activities included	Interest rate used in discount factor
A	Discounted total returns of terminal planning year	Capital selling	5%
B	Sum of discounted net returns of the 3 years	Capital selling	5%
C	Discounted total returns of terminal planning year	No capital selling	5%
D	Sum of discounted net returns of the 3 years	No capital selling	5%
E	Discounted total returns of terminal planning year	Capital selling with 20% interest rate	20%
F	Sum of discounted net returns of the 3 years	Capital selling with 20% interest rate	20%

The optimal plan for each of the six models is presented in Table 6. It can be seen that the allocation of resources in the three models does not differ greatly. What differs from one model to the other is the level of profits or returns. The crop activities selected (C-C-C and C-C-O-M-M) and the hog enterprise appear at the same level in the six optimal plans. All models include in their optimal plan 188.4 acres of the first rotation and 11.6 acres of the second one. Likewise, all plans include 21 units of hogs each year.

The limiting resource in every year of the plan is labor. Capital is not limiting in the first year: $640 is allocated to the capital selling activity or to capital disposal according to the model.

Models A, C and E maximize discounted total returns. The respective amounts are $36,895, $32,946 and $24,526. Model A includes a selling activity which explains the higher returns than in the other two

Table 6. Level of selected activities in 3-year optimal plans for a 200-

Year	Activity Name	Model A	Model B	Model
0	Family living	$5400	$5400	$5400
0	C-C-C	118.4 acres	188.4 acres	188.4
0	C-C-O-M-M	11.6 acres	11.6 acres	11.6
0	Corn Selling	8523 bu.	8538 bu.	9036
0	Capital Selling	$640	$640	-
0	Capital Disposal	-	-	-
0	Corn Buying	-	-	515
0	Hogs	21 units	21 units	21
1	Corn Selling	8537 bu.	8538 bu.	8539
1	Capital Selling	$9985	$9321	-
1	Capital Disposal	-	-	-
1	Corn Buying	-	-	7991
1	Hogs	21 units	21 units	21
2	Corn Selling	8538 bu.	8538 bu.	233
2	Capital Selling	$19681	$9297	$
2	Capital Disposal	-	-	
2	Corn Buying	-	-	
2	Hogs	-	-	14
3	Discounted total or net returns[a]	$36895	$39681	$3

[a] Models A,C and E maximize total returns. Models B,D, and F m

or a 200-acres farm obtained by using different dynamic programing models.

Model C	Model D	Model E	Model F
$5400	$5400	$5400	$5400
188.4 acres	188.4 acres	188.4 acres	188.4 acres
11.6 acres	11.6 acres	11.6 acres	11.6 acres
9036 bu.	9522 bu.	8523 bu.	8523 bu.
-	-	$640	$640
-	$640	-	-
515 bu.	-	-	-
21 units	21 units	21 units	21 units
8539 bu.	16528 bu.	8539 bu.	8539 bu.
-	-	$9984	$9320
-	$9320	-	-
7991 bu.	-	-	-
21 units	21 units	21 units	21 units
23380 bu.	8538 bu.	8539 bu.	8538 bu.
$ -	-	$19630	$9297
-	$9297	-	-
-	-	-	-
14842 bu.	-	21 units	21 units
$32946	$38963	$24526	$30904

', and F maximize net returns.

models. Model B has no capital selling activity and Model E has a selling activity but with an interest rate of 20%. This explains the relative lower level of returns in Model E's optimal plan.

Models B, D and F maximize the sum of discounted net returns for the three years included in the plan. These amount to $39,681, $38,963 and $30,904. Model B has a selling activity which accounts for the higher level of profits obtained in this model's optimum plan.

Model D's optimum plan includes a corn buying activity. To have a corn buying activity (with higher price relatively to the corn selling activity) and a corn selling activity appearing in the same optimal plan looks inconsistent. It is explained by the fact that if a model has no capital selling activity the excess capital supply becomes a free resource. It can then be used to even buy corn which is sold at a lower price.[1]

Apparently, the internal rate of growth is greater than the external rate of 20% in Models E and F. The optimal plans of these two models show the same allocation of resources as in Models A and B, although the level of returns is different. It remains to be seen whether or not the optimum plan would change when the level of capital is varied and it becomes limiting in the first year.

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[1]When net returns are maximized as in Model D, the corn buying activity does not come into the optimum plan, because it has a negative price, -1.24, contrariwise to Model C in which its price is zero.

D. A Model for an Owner-Operated Farm

The logic and technique of the model presented in Figure 4 can be explained by making a brief statement of the activities and restrictions of each year. Some necessary simplifications have been made for explanatory purposes.

1. Restrictions and activities in year k=0

The resource restrictions in year k=0 are land, capital, hay, corn, livestock building space and labor. These are denoted by $b_{1,0}$, $b_{2,0}$, $b_{3,0}$, $b_{4,0}$, $b_{5,0}$, $b_{6,0}$. Of these six restrictions there are four which have positive values in the original matrix. The hay and corn restrictions $b_{3,0}$ and $b_{4,0}$, are equal to zero because no feed has yet been produced.

There are two more restrictions in year 0 which cannot be included among the resource supplies. These are family consumption and capital rationing, b_7 and $b_{8,0}$.

The family consumption restriction permits the annual withdrawal of funds from capital resources. This restriction, b_7, carries no year subscript because it represents the amount consumed in all the four years of the plan. Family consumption is expressed by an artificial activity or column P_1 in our model. This activity must be forced into the program according to the assumptions of the model. Thus, operating funds in the first year and in any other year will not be available for the real activities as long as P_1, affixed with an arbitrarily large price + M, does not come into the program at the full level of the family living

Figure 4. A four-year dynamic linear programming model for an owner-operated farm

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			$d_j \longrightarrow$	+M						$d_{7,3}$	$d_{8,3}$
Year	Resource used or activity produced	P_0	Supply, remainder or output	Family living P_1	Hogs 0 P_2	Hogs 1 P_3	Hogs 1 P_4	Hogs 2 P_5	Hogs 2 P_6	Hogs 3 P_7	Hogs 3 P_8
0	Land	P_{42}	$b_{1,0}$								
0	Capital	P_{43}	$b_{2,0}$	$a_{2,1,0}+1$	$a_{2,2,0}$						
0	Hay	P_{44}	$b_{3,0}$		$a_{3,2,0}$						
0	Corn	P_{45}	$b_{4,0}$		$a_{4,2,0}$						
0	Livestock space	P_{46}	$b_{5,0}$		$a_{5,2,0}$						
0	Labor	P_{47}	$b_{6,0}$		$a_{6,2,0}$						
	Family living	P_{48}	b_7	$a_{7,1,0}+1$							
0	Capital rationing	P_{49}	$b_{8,0}$								
1	Land	P_{50}	$b_{9,1}$								
1	Capital	P_{51}	$b_{10,1}$	$a_{10,1,1}+1$	$-a_{10,2,1}$	$a_{10,3,1}$	$a_{10,4,1}$				
1	Hay	P_{52}	$b_{11,1}$			$a_{11,3,1}$	$a_{11,4,1}$				
1	Corn	P_{53}	$b_{12,1}$			$a_{12,3,1}$	$a_{12,4,1}$				
1	Livestock space	P_{54}	$b_{13,1}$			$a_{13,3,1}$	$a_{13,4,1}$				
1	Livestock equipment	P_{55}	$b_{14,1}$		$-a_{14,2,1}$	$a_{14,3,1}$					
1	Labor	P_{56}	$b_{15,1}$			$a_{15,3,1}$	$a_{15,4,1}$				
1	Capital rationing	P_{57}	$b_{16,1}$								
2	Land	P_{58}	$b_{17,2}$								
2	Capital	P_{59}	$b_{18,2}$	$a_{18,1,2}+1$		$-a_{18,3,2}$	$-a_{18,4,2}$	$a_{18,5,2}$	$a_{18,6,2}$		
2	Hay	P_{60}	$b_{19,2}$					$a_{19,5,2}$	$a_{19,6,2}$		
2	Corn	P_{61}	$b_{20,2}$					$a_{20,5,2}$	$a_{20,6,2}$		
2	Livestock space	P_{62}	$b_{21,2}$					$a_{21,5,2}$	$a_{21,6,2}$		
2	Livestock equipment	P_{63}	$b_{22,2}$		$-a_{22,2,2}$		$-a_{22,4,2}$	$a_{22,5,2}$			
2	Labor	P_{64}	$b_{23,2}$					$a_{23,5,2}$	$a_{23,6,2}$		
2	Capital rationing	P_{65}	$b_{24,2}$								
3	Land	P_{66}	$b_{25,3}$								
3	Turned land	P_{67}	$b_{26,3}$								
3	Capital	P_{68}	$b_{27,3}$	$a_{27,1,3}+1$				$-a_{27,5,3}$	$-a_{27,6,3}$	$a_{27,7,3}$	$a_{27,8,3}$
3	Hay	P_{69}	$b_{28,3}$							$a_{28,7,3}$	$a_{28,8,3}$
3	Corn	P_{70}	$b_{29,3}$							$a_{29,7,3}$	$a_{29,8,3}$
3	Livestock space	P_{71}	$b_{30,3}$							$a_{30,7,3}$	$a_{30,8,3}$
3	Livestock equipment	P_{72}	$b_{31,3}$		$-a_{31,2,3}$		$-a_{31,4,3}$		$-a_{31,6,3}$	$a_{31,7,3}$	
3	Labor	P_{73}	$b_{32,3}$								
3	Capital rationing	P_{74}	$b_{33,3}$								
	$\Sigma p_j - d_j$	P_{75}	0	$z_1 - d_1$	$z_{2,0} - d_{1,0}$	....					

Year	Resource used or activity produced	P_0	BOT $COM_{1,1,0}$ P_9	$COM_{2,1,0}$ P_{10}	$COM_{1,2,0}$ P_{11}	$COM_{2,2,0}$ P_{12}	$COM_{1,1,1}$ P_{13}	$COM_{2,1,1}$ P_{14}	$COM_{1,2,1}$ P_{15}	$COM_{2,2,1}$ P_{16}
0	Land	P_{42}	$a_{1,9,0}+1$	$a_{1,10,0}+1$	$a_{1,11,0}+1$	$a_{1,12,0}+1$				
0	Capital	P_{43}	$a_{2,9,0}$	$a_{2,10,0}$	$a_{2,11,0}$	$a_{2,12,0}$				
0	Hay	P_{44}	$-a_{3,9,0}$	$-a_{3,10,0}$	$-a_{3,11,0}$	$-a_{3,12,0}$				
0	Corn	P_{45}	$-a_{4,9,0}$	$-a_{4,10,0}$	$-a_{4,11,0}$	$-a_{4,12,0}$				
0	Livestock space	P_{46}								
0	Labor	P_{47}	$a_{6,9,0}$	$a_{6,10,0}$	$a_{6,11,0}$	$a_{6,12,0}$				
	Family living	P_{48}								
0	Capital rationing	P_{49}								
1	Land	P_{50}	$a_{9,9,1}+1$	$a_{9,10,1}+1$	$a_{9,11,1}+1$	$a_{9,12,1}+1$	$a_{9,13,1}+1$	$a_{9,14,1}+1$	$a_{9,15,1}+1$	$a_{9,16,1}+1$
1	Capital	P_{51}	$a_{10,9,1}$	$a_{10,10,1}$	$a_{10,11,1}$	$a_{10,12,1}$	$a_{10,13,1}$	$a_{10,14,1}$	$a_{10,15,1}$	$a_{10,16,1}$
1	Hay	P_{52}	$-a_{11,9,1}$	$-a_{11,10,1}$	$-a_{11,11,1}$	$-a_{11,12,1}$	$-a_{11,13,1}$	$-a_{11,14,1}$	$-a_{11,15,1}$	$-a_{11,16,1}$
1	Corn	P_{53}	$-a_{12,9,1}$	$-a_{12,10,1}$	$-a_{12,11,1}$	$-a_{12,12,1}$	$-a_{12,13,1}$	$-a_{12,14,1}$	$-a_{12,15,1}$	$-a_{12,16,1}$
1	Livestock space	P_{54}								
1	Livestock equipment	P_{55}								
1	Labor	P_{56}	$a_{15,9,1}$	$a_{15,10,1}$	$a_{15,11,1}$	$a_{15,12,1}$	$a_{15,13,1}$	$a_{15,14,1}$	$a_{15,15,1}$	$a_{15,16,1}$
1	Capital rationing	P_{57}								
2	Land	P_{58}	$a_{17,9,2}+1$	$a_{17,10,2}+1$	$a_{17,11,2}+1$	$a_{17,12,2}+1$	$a_{17,13,2}+1$	$a_{17,14,2}+1$	$a_{17,15,2}+1$	$a_{17,16,2}+1$
2	Capital	P_{59}	$a_{18,9,2}$	$a_{18,10,2}$	$a_{18,11,2}$	$a_{18,12,2}$	$a_{18,13,2}$	$a_{18,14,2}$	$a_{18,15,2}$	$a_{18,16,2}$
2	Hay	P_{60}	$-a_{19,9,2}$	$-a_{19,10,2}$	$-a_{19,11,2}$	$-a_{19,12,2}$	$-a_{19,13,2}$	$-a_{19,14,2}$	$-a_{19,15,2}$	$-a_{19,16,2}$
2	Corn	P_{61}	$-a_{20,9,2}$	$-a_{20,10,2}$	$-a_{20,11,2}$	$-a_{20,12,2}$	$-a_{20,13,2}$	$-a_{20,14,2}$	$-a_{20,15,2}$	$-a_{20,16,2}$
2	Livestock space	P_{62}								
2	Livestock equipment	P_{63}								
2	Labor	P_{64}	$a_{23,9,2}$	$a_{23,10,2}$	$a_{23,11,2}$	$a_{23,12,2}$	$a_{23,13,2}$	$a_{23,14,2}$	$a_{23,15,2}$	$a_{23,16,2}$
2	Capital rationing	P_{65}								
3	Land	P_{66}					$a_{25,13,3}+1$	$a_{25,14,3}+1$	$a_{25,15,3}+1$	$a_{25,16,3}+1$
3	Turned land	P_{67}			$-a_{26,11,3}+1$	$-a_{26,12,3}+1$				
3	Capital	P_{68}					$a_{27,13,3}$	$a_{27,14,3}$	$a_{27,15,3}$	$a_{27,16,3}$
3	Hay	P_{69}					$-a_{28,13,3}$	$-a_{28,14,3}$	$-a_{28,15,3}$	$-a_{28,16,3}$
3	Corn	P_{70}					$-a_{29,13,3}$	$-a_{29,14,3}$	$-a_{29,15,3}$	$-a_{29,16,3}$
3	Livestock space	P_{71}								
3	Livestock equipment	P_{72}								
3	Labor	P_{73}					$a_{32,13,3}$	$a_{32,14,3}$	$a_{32,15,3}$	$a_{32,16,3}$
3	Capital rationing	P_{74}								
	$\Sigma p_j - d_j$	P_{75}			...... $\Sigma p_j d_j$					

Year	Resource used or activity produced	P_0	$COM_{1,1,2}$ P_{17}	$COM_{2,1,2}$ P_{18}	$COM_{1,2,2}$ P_{19}	$COM_{2,2,2}$ P_{20}	$COM_{1,1,3}$ P_{21}	$COM_{2,1,3}$ P_{22}	$COM_{1,2,3}$ P_{23}	[illegible]
0	Land	P_{42}								
0	Capital	P_{43}								
0	Hay	P_{44}								
0	Corn	P_{45}								
0	Livestock space	P_{46}								
0	Labor	P_{47}								
	Family living	P_{48}								
0	Capital rationing	P_{49}								
1	Land	P_{50}								
1	Capital	P_{51}								
1	Hay	P_{52}								
1	Corn	P_{53}								
1	Livestock space	P_{54}								
1	Livestock equipment	P_{55}								
1	Labor	P_{56}								
1	Capital rationing	P_{57}								
2	Land	P_{58}	$a_{17,17,2}+1$	$a_{17,18,2}+1$	$a_{17,19,2}$	$a_{17,20,2}$				
2	Capital	P_{59}	$a_{18,17,2}$	$a_{18,18,2}$	$a_{18,19,2}$	$a_{18,20,2}$				
2	Hay	P_{60}	$-a_{19,17,2}$	$-a_{19,18,2}$	$-a_{19,19,2}$	$-a_{19,20,2}$				
2	Corn	P_{61}	$-a_{20,17,2}$	$-a_{20,18,2}$	$-a_{20,19,2}$	$-a_{20,20,2}$				
2	Livestock space	P_{62}								
2	Livestock equipment	P_{63}								
2	Labor	P_{64}	$a_{23,17,2}$	$a_{23,18,2}$	$a_{23,19,2}$	$a_{23,20,2}$				
2	Capital rationing	P_{65}								
3	Land	P_{66}	$a_{25,17,3}+1$	$a_{25,18,3}+1$	$a_{25,19,3}+1$	$a_{25,20,3}+1$	$a_{25,21,3}+1$	$a_{25,22,3}+1$	$a_{25,23,3}+1$	a2
3	Turned land	P_{67}								
3	Capital	P_{68}	$a_{27,17,3}$	$a_{27,18,3}$	$a_{27,19,3}$	$a_{27,20,3}$	$a_{27,21,3}$	$a_{27,22,3}$	$a_{27,23,3}$	a2
3	Hay	P_{69}	$-a_{28,17,3}$	$-a_{28,18,3}$	$-a_{28,19,3}$	$-a_{28,20,3}$	$-a_{28,21,3}$	$-a_{28,22,3}$	$-a_{28,23,3}$	-a2
3	Corn	P_{70}	$-a_{29,17,3}$	$-a_{29,18,3}$	$-a_{29,19,3}$	$-a_{29,20,3}$	$-a_{29,21,3}$	$-a_{29,22,3}$	$-a_{29,23,3}$	-a2
3	Livestock space	P_{71}								
3	Livestock equipment	P_{72}								
3	Labor	P_{73}	$a_{32,17,3}$	$a_{32,18,3}$	$a_{32,19,3}$	$a_{32,20,3}$	$a_{32,21,3}$	$a_{32,22,3}$	$a_{32,23,3}$	a3
3	Capital rationing	P_{74}								
	$\Sigma p_j - d_j$	P_{75}								

$COM_{2,1,2}$ P_{18}	$COM_{1,2,2}$ P_{19}	$COM_{2,2,2}$ P_{20}	$COM_{1,1,3}$ P_{21}	$COM_{2,1,3}$ P_{22}	$COM^{I}_{1,2,3}$ P_{23}	$COM_{2,2,3}$ P_{24}	$COM^{T}_{1,2,3}$ P_{25}	$COM^{T}_{2,2,3}$ P_{26}	Corn buying$_0$ P_{27}	Corn selling$_1$ P_{28}	Corn selling$_2$ P_{29}	Corn selling$_3$ P_{30}	Capital selling$_0$ P_{31}	Capital selling$_1$ P_{32}	Capital selling$_2$ P_{33}	Capital selling$_3$ P_{34}	Capital borrowing$_0$ P_{35}	Capital borrowing$_1$ P_{36}	Capital borrowing$_2$ P_{37}	Capital borrowing$_3$ P_{38}	Hay transfer P_{39}	Hay transfer P_{40}	Hay selling P_{41}	Land disposal P_{62} ....
												$d_{30,1}$				$d_{34,1}$				$-d_{38,1}$				
																								1
									$a_{2,27,0}=1.34$				$a_{2,31,0}=1$				$-a_{2,35,0}=-1$							
																					$a_{1,39,0}=-1$			
									$a_{4,27,0}=-1$															
																	$a_{6,35,0}=1$							
										$-a_{10,28,1}=-1.14$			$-a_{10,31,1}$	$a_{10,32,1}=1$			$a_{10,35,1}=1$	$-a_{10,36,1}=-1$						
																					$-a_{11,39,1}=-1$	$a_{11,40,1}=1$		
										$a_{12,28,1}=1$														
																		$a_{16,36,1}=-1$						
$_{7,18,2}=1$	$a_{17,19,2}$	$a_{17,20,2}$																						
$_{8,18,2}$	$a_{18,19,2}$	$a_{18,20,2}$									$-a_{18,29,2}=-1.14$			$-a_{18,32,2}$	$a_{18,33,2}=1$			$a_{18,36,2}=1$	$-a_{18,37,2}$					
$_{9,18,2}$	$-a_{19,19,2}$	$-a_{19,20,2}$																				$-a_{19,40,2}=-1$	$a_{19,41,2}=1$	
$_{0,18,2}$	$-a_{20,19,2}$	$-a_{20,20,2}$									$a_{20,29,2}=1$													
$_{3,18,2}$	$a_{23,19,2}$	$a_{23,20,2}$																						
																			$a_{24,37,2}$					
$_{5,18,3}=1$	$a_{25,19,3}=1$	$a_{25,20,3}=1$	$a_{25,21,3}=1$	$a_{25,22,3}=1$	$a_{25,23,3}=1$	$a_{25,24,3}=1$	$a_{25,25,3}=1$	$a_{25,26,3}=1$																
							$a_{26,25,3}=1$	$a_{26,26,3}=1$																
$_{7,18,3}$	$a_{27,19,3}$	$a_{27,20,3}$	$a_{27,21,3}$	$a_{27,22,3}$	$a_{27,23,3}$	$a_{27,24,3}$	$a_{27,25,3}$	$a_{27,26,3}$							$-a_{27,33,3}=-4.035$	$a_{27,34,3}=1$			$a_{27,37,3}=1$	$-a_{27,38,3}$				
$_{1,18,3}$	$-a_{28,19,3}$	$-a_{28,20,3}$	$-a_{28,21,3}$	$-a_{28,22,3}$	$-a_{28,23,3}$	$-a_{28,24,3}$	$-a_{28,25,3}$	$-a_{28,26,3}$															$-a_{28,41,3}$	
$_{,18,3}$	$-a_{29,19,3}$	$-a_{29,20,3}$	$-a_{29,21,3}$	$-a_{29,22,3}$	$-a_{29,23,3}$	$-a_{29,24,3}$	$-a_{29,25,3}$	$-a_{29,26,3}$				$a_{29,30,3}$												
$_{,18,3}$	$a_{32,19,3}$	$a_{32,20,3}$	$a_{32,21,3}$	$a_{32,22,3}$	$a_{32,23,3}$	$a_{32,24,3}$	$a_{32,25,3}$	$a_{33,26,3}$																
																				$a_{33,38,3}=-1$				

.... $l_{41,3}=a_{41,3}$ ....

restriction.[1] In a more refined model the family living restriction should be allowed to increase above the minimum level of family consumption.

The capital rationing restriction has a role similar to that of the family living restriction. Capital borrowing is also expressed by an activity x_{jk}, ($P_{35,0}$ for year k=0 in the model). Capital borrowed by the farmer may have different costs according to the farmer's subjective discount rates and actual borrowing charges. In other words, the entrepreneur may be affected by internal and external capital rationing. Hence, at a given rate of interest only a limited amount may be loaned to a farmer. Any amount borrowed in excess of this minimum will make the rate of interest go up. Hence the capital rationing restriction indicates the amount of capital available at the first given rate of interest. In a less simplified model than this, more than one capital borrowing activity at progressively higher rates would demand a corresponding number of additional capital rationing restrictions.

Crop activities in year k=0 include a rotation at different levels of fertilization and conservation practices. The levels of fertilization and conservation are indicated by the first two subscripts attached to the rotation name. The year the rotation starts is symbolized by the last

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[1]The pseudo-returns obtained from this artificial activity most be substracted from the total returns of the optimal feasible solution. For that reason, it is perhaps more convenient to affix the disposal or slack variable of the family living restriction with an arbitrarily large price -M which will force out the disposal (hence bringing in P_1) without affecting the level of returns of the final plan.

subscript. For instance, $COM_{1,1,0}$, P_9, means a three-year rotation of corn, oats and meadow starting in year k=0 using a low level of fertilization and contouring. $COM_{2,2,1}$, P_{16}, is the same rotation starting in year k=1 using high fertilization and terracing.

Each rotation uses land, capital and labor. Hence the a_{ijk} coefficients carry a positive sign. For example, one unit of $COM_{1,1,0}$, i.e., P_9, uses $a_{1,9,0} = 1$ of land, $a_{2,9,0}$ of capital and $a_{6,9,0}$ of labor.

In year k=0 each rotation produces hay. Hence, the coefficient corresponding to the hay supply is negative. In $COM_{1,1,0}$, the hay production is signified by the negative coefficient $-a_{3,9,0}$ in the hay restriction row i=3. Notice that in year k=0 the coefficient in the corn row restriction for all the activities starting in that year only represents the oats produced in that year. The reason is that corn, contrariwise to oats, is produced that year but is not fed until the beginning of the following year.

In order to simplify computations it is assumed that each unit of crop rotation, i.e., one acre, is evenly distributed between the crops composing that rotation. In the COM example, each acre grows one third of corn, one third of oats and one third of meadow during every year which the rotation lasts. The same plot of land is assumed to successively rotate the three crops in the three-year duration of the rotation.[1]

[1]This interpretation of a crop activity in dynamic model simplifies considerably the computations. The different coefficients remain unaltered during the three years.

the number of land restrictions would be increased. The reason is that land yields differently according to the crop grown in the previous years. Consequently, the same plot of land following different crops would need different land restrictions. In large empirical problems the multiplication of land restrictions may make the computations unmanageable.

The only livestock activity in year 0 is hog production. P_2 requires $a_{2,2,0}$ dollars of capital, $a_{3,2,0}$ tons of hay, $a_{4,2,0}$ bushels of corn, $a_{5,2,0}$ square feet of building space and $a_{6,2,0}$ hours of labor. All these coefficients carry a positive sign.

The remaining activities of year 0 are corn buying (P_{27}), Capital welling or external investment (P_{32}) and capital borrowing (P_{35}). Corn buying uses $a_{2,27,0}$ dollars of the capital supply and increases the corn supply, $b_{4,0}$, by $-a_{4,27,0}$ bushels, i.e., one bushel. Capital selling, P_{31}, is an inter-year activity. One dollar of external investment in year 0 will produce $-a_{10,31,1}$ dollars in year 1. Hay transfer, P_{39}, is another inter-year activity. Its purpose is to permit the use of hay disposal of year 0 in year 1. Hence, it uses one unit of hay in year 0, $a_{3,39,0}$, and "produces" one unit in year 1, $-a_{11,39,1}$.

It is important to notice that all the activities of year 0 have a zero price. There is one exception, however. This is the family living activity, P_1, which has a price +M as explained above.. Now, if any of the activities of year 0 having a zero price produce any returns, these returns appear in the capital row of the following year with a negative sign. This statement needs a qualification, however. It does not apply to crop activities as it will be explained in the next section.

2. Restrictions and activities of year 1

The restrictions in year 1 are the same as in year 0 with one exception. There is a new restriction $b_{14,1}$, Livestock Equipment. It is included to account for the previous year's investment in equipment of livestock activities. The value of that type of equipment is ordinarily not included in the fixed costs of the farm. Hence the need of a new restriction row $b_{14,1}$, which shows the amount of livestock equipment "produced" in year 0.

It can be noticed that in year 1 there are two hog activities, P_3 and P_4. In technical terms they are the same: they consume the same amount of inputs and produce the same amount of output. In economic terms they are different, however. Their capital coefficients, $a_{10,3,1}$ and $a_{10,4,1}$, are different. The first does not include the expense due to special equipment. The second has a higher value than the first b ecause it includes the cost of livestock equipment. The first activity, P_3, yields higher net returns because it uses equipment purchased in the previous year (or years). Hence, the positive $a_{14,3,1}$ in the livestock equipment row which means that P_3 uses up that equipment.

The second hog activity, P_4, has a zero coefficient in that same row. This implies that if the hog producing activity's opportunity cost is high, after using up the previous year's livestock equipment(P_3 comes into the plan), a new activity, P_4, comes into the plan. The capital coefficient of the latter, $a_{10,4,1}$, includes the per unit cost of the equipment. Consequently, the inclusion of a double livestock activity every year is intended to give more flexibility to the model.

The second hog activity, P_4, has a zero coefficient in that same row. This implies that if the hog producing activity's opportunity cost is high, after using up the previous year's livestock equipment (P_3 comes into the plan), a new activity, P_4, comes into the plan. The capital coefficient of the lätter, $a_{10,4,1}$, includes the per unit cost of the equipment. Consequently, the inclusion of a double livestock activity every year is intended to give more flexibility to the model.

The same function fulfills the four rotation activities starting in year 1: P_{13}, P_{14}, P_{15}, and P_{16}, Land which due to lack of capital could have been in disposal in year 0, can be employed in later years as capital resources are built up.

An important feature of the model is that crops which are just produced do not realize any returns. All the coefficients in the d_{jk} row corresponding to crop activities are zero. The reason is that returns from crops are only realized when transferred to a selling activity and marketed. The corn selling activity for year 1 is P_{28}. It has a positive $a_{12, 28,1}=1$ in the corn row and a negative $-a_{10,28,1}= -1.14$ (assuming the selling price of corn is \$1.14 per bushel). This means that for every unit of corn which is sold there is a return of \$1.14. Likewise, hay returns are realized through a hay selling activity, P_{41}.

3. <u>Restrictions and activities of year 2 and year 3</u>

The activities and restrictions of year 2 do not present any new characteristic. They follow the same logic as those of the previous year.

In year 3 and the last included in the plan a new restriction appears for the first time, namely terraced land, $b_{26,3}$. Consider the four three-year rotations starting in year k=0. Two of them, P_9 and P_{10}, use a low level of conservation practices. The other two, P_{11} and P_{12}, use terracing, that is, a high level of conservation. After three years have elapsed, two types of land will be freed for production.[1] The first has no terraces and the second possesses them. Hence, P_{11} and P_{12} have a negative coefficient, $-a_{26,11,3} = -1$ and $-a_{26,12,3} = -1$, in the terraced land restriction, $b_{26,3}$.

The rotation activities starting in year k=3 present also a difference with regard to previous years. There are in effect two new activities: $COM^T_{1,2,3}$ and $COM^T_{2,2,3}$, P_{25} and P_{26}. They have a positive coefficient equal to 1 in the terraced land row because they use, apart from the usual unit of land resource, $b_{25,3}$, an additional unit of terraced land resource, $b_{26,3}$.

Notice that there are in the same year other activities which employ terracing, namely P_{23} and P_{24}. These activities require a larger amount of capital than P_{25} and P_{26}, however. The reason is that the latter do not include the capital expense due to terracing; the terraced have been already built in year k=0.

The last point worth mentioning about the model is that there are only five non-zero prices in the d_{jk} row: those corresponding to hog activities, P_7 and P_8, corn selling$_3$, P_{30}, capital selling, P_{34}, hay

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[1]According to our assumptions regarding rotation activities all land after that particular rotation has the same level of fertility.

$selling_3$, P_{42}, and capital borrowing, P_{38}. The first four are positive and are discounted to their present value in year k=0. All returns are realized through these four activities.

Capital $borrowing_3$, P_{37}, carries a negative sign in its corresponding price, $d_{38,3}$. Evidently, it represents the payment of the amount borrowed by P_{37} plus the interest rate on the loan. This is substracted from the total returns of the firm.

There are other activities in the matrix which for simplicity are not presented in Figure 4. These are the disposal or slack variables which form the unit matrix of order mxm.

The last row of the matrix, $z_{jk}-d_{jk}$ is the criterion row. It indicates the amount by which returns will be increased if the activity level is increased by one unit. In that same row in the P_o's or resource, output or supply remainer column, the levels of total returns of each plan is indicated.

E. A Dynamic Model for a Crop-Share Rented Farm

In Figure 5 a three-year dynamic linear programming model for a share-rented farm is presented. The logic of this model and the one presented above is essentially the same. The main difference between the two models is that in the new model there are two groups of activities and restrictions: those pertaining to the tenant and those to the landlord. Likewise, there are two price rows, d^L_{jk} and d^T_{jk}, and two marginal revenue rows, $z^L_{jk} - d^L_{jk}$ and $z^T_{jk} - d^T_{jk}$. In order to avoid repetition only the features in which the two models specifically differ will be explained below.

Figure 5. A three-year dynamic programming model for a crop-share rented farm

d^I_{jk} ----> $\leq M$

d^T_{jk} ----> $\leq M$

$d^T_{5,2}$ $d^T_{6,2}$

Year	Resource used activity produced	P	Supply, remainder or output	Family living P_1	Hogs$_0$ P_2	Hogs$_1$ P_3	Hogs$_1$ P_4	Hogs$_2$ P_5	Hogs$_2$ P_6	COM$_{1,1,0}$ P_7	COM$_{2,1,0}$ P_8	COM$_{1,2,0}$ P_9	COM$_{2,2,0}$ P_{10}	COM$_{1,1,1}$ P_{11}	COM$_{2,1,1}$ P_{12}	COM$_{1,2,1}$ P_{13}	COM$_{2,2,1}$ P_{14}	COM$_{1,1,2}$ P_{15}	COM$_{2,1,2}$ P_{16}	COM$_{1,2,2}$ P_{17}	COM$_{2,2,2}$ P_{18}	Corn buying$^T_0$ P_{19}	Corn buying P_{20}
0	Land	P_{36}	$b_{1,0}$							$a_{1,7,0}=1$	$a_{1,8,0}$	$a_{1,9,0}$	$a_{1,10,0}$										
0	Capital I.	P_{37}	$b_{2,0}$							$\pm a_{2,7,0}$	$\pm a_{2,8,0}$	$\pm a_{2,9,0}$	$\pm a_{2,10,0}$										
0	Capital T.	P_{38}	$b_{3,0}$	$a_{1,1,0}=-1$	$a_{3,2,0}$					$a_{3,7,0}$	$a_{3,8,0}$	$a_{3,9,0}$	$a_{3,10,0}$									$a_{3,19,0}=1.24$	
0	Hay	P_{39}	$b_{4,0}$		$a_{4,2,0}$					$-a_{4,7,0}$	$-a_{4,8,0}$	$-a_{4,9,0}$	$-a_{4,10,0}$										
0	Corn I.	P_{40}	$b_{5,0}$							$-a_{5,7,0}$	$-a_{5,8,0}$	$-a_{5,9,0}$	$-a_{5,10,0}$										
0	Corn T.	P_{41}	$b_{6,0}$		$a_{6,2,0}$					$-a_{6,7,0}$	$-a_{6,8,0}$	$-a_{6,9,0}$	$-a_{6,10,0}$									$-a_{6,19,0}=1$	
0	Livestock space	P_{42}	$b_{7,0}$		$a_{7,2,0}$																		
0	Labor	P_{43}	$b_{8,0}$		$a_{8,2,0}$					$a_{8,7,0}$	$a_{8,8,0}$	$a_{8,9,0}$	$a_{8,10,0}$										
	Family living	P_{44}	b_9	$a_{9,1,0}=1$																			
0	Capital rationing	P_{45}	$b_{10,0}$		$a_{10,2,0}$																		
1	Land	P_{46}	$b_{11,1}$							$a_{11,7,1}$	$a_{11,8,1}$	$a_{11,9,1}$	$a_{11,10,1}$	$a_{11,11,1}$	$a_{11,12,1}$	$a_{11,13,1}$	$a_{11,14,1}$						
1	Capital I.	P_{47}	$b_{12,1}$							$\pm a_{12,7,1}$	$\pm a_{12,8,1}$	$\pm a_{12,9,1}$	$\pm a_{12,10,1}$	$\pm a_{12,11,1}$	$\pm a_{12,12,1}$	$\pm a_{12,13,1}$	$\pm a_{12,14,1}$						
1	Capital T.	P_{48}	$b_{13,1}$	$a_{13,1,1}=-1$	$-a_{11,2,1}$	$a_{11,3,1}$	$a_{13,4,1}$			$a_{13,7,1}$	$a_{13,8,1}$	$a_{13,9,1}$	$a_{13,10,1}$	$a_{13,11,1}$	$a_{13,12,1}$	$a_{13,13,1}$	$a_{13,14,1}$						$a_{13,20,1}=$
1	Hay	P_{49}	$b_{14,1}$			$a_{14,3,1}$	$a_{14,4,1}$			$-a_{14,7,1}$	$-a_{14,8,1}$	$-a_{14,9,1}$	$-a_{14,10,1}$	$-a_{14,11,1}$	$-a_{14,12,1}$	$-a_{14,13,1}$	$-a_{15,14,1}$						
1	Corn I.	P_{50}	$b_{15,1}$							$-a_{15,7,1}$	$-a_{15,8,1}$	$-a_{15,9,1}$	$-a_{15,10,1}$	$-a_{15,11,1}$	$-a_{15,12,1}$	$-a_{15,13,1}$	$-a_{15,14,1}$						
1	Corn T.	P_{51}	$b_{16,1}$			$a_{16,3,1}$	$a_{16,4,1}$			$-a_{16,7,1}$	$-a_{16,8,1}$	$-a_{16,9,1}$	$-a_{16,10,1}$	$-a_{16,11,1}$	$-a_{16,12,1}$	$-a_{17,13,1}$	$-a_{18,14,1}$						$-a_{16,20,1}=$
1	Livestock space	P_{52}	$b_{17,1}$			$a_{17,3,1}$	$a_{17,4,1}$																
1	Livestock equipment	P_{53}	$b_{18,1}$		$-a_{18,2,1}$	$a_{18,3,1}$																	
1	Labor	P_{54}	$b_{19,1}$			$a_{19,3,1}$	$a_{19,4,1}$			$a_{19,7,1}$	$a_{19,8,1}$	$a_{19,9,1}$	$a_{19,10,1}$	$a_{19,11,1}$	$a_{19,12,1}$	$a_{19,13,1}$	$a_{19,14,1}$						
1	Capital rationing	P_{55}	$b_{20,1}$																				
2	Land	P_{56}	$b_{21,2}$							$a_{21,7,2}$	$a_{21,8,2}$	$a_{21,9,2}$	$a_{21,10,2}$	$a_{21,11,2}$	$a_{21,12,2}$	$a_{21,13,2}$	$a_{21,14,2}$	$a_{21,15,2}$	$a_{21,16,2}$	$a_{21,17,2}$	$a_{21,18,2}$		
2	Capital I.	P_{57}	$b_{22,2}$							$\pm a_{22,7,2}$	$\pm a_{22,8,2}$	$\pm a_{22,9,2}$	$\pm a_{22,10,2}$	$\pm a_{22,11,2}$	$\pm a_{22,12,2}$	$\pm a_{22,13,2}$	$\pm a_{22,14,2}$	$\pm a_{22,15,2}$	$\pm a_{22,16,2}$	$\pm a_{22,17,2}$	$\pm a_{22,18,2}$		
2	Capital T.	P_{58}	$b_{23,2}$	$a_{23,1,2}=-1$		$-a_{21,3,2}$	$-a_{21,4,2}$	$a_{23,5,2}$	$a_{23,6,2}$	$a_{23,7,2}$	$a_{23,8,2}$	$a_{23,9,2}$	$a_{23,10,2}$	$a_{23,11,2}$	$a_{23,12,2}$	$a_{23,13,2}$	$a_{23,14,2}$	$a_{23,15,2}$	$a_{23,16,2}$	$a_{23,17,2}$	$a_{23,18,2}$		
2	Hay	P_{59}	$b_{24,2}$					$a_{24,5,2}$	$a_{24,6,2}$	$-a_{24,7,2}$	$-a_{24,8,2}$	$-a_{24,9,2}$	$-a_{24,10,2}$	$-a_{24,11,2}$	$-a_{24,12,2}$	$-a_{24,13,2}$	$-a_{24,14,2}$	$-a_{24,15,2}$	$-a_{24,16,2}$	$-a_{24,17,2}$	$-a_{24,18,2}$		
2	Corn I.	P_{60}	$b_{25,2}$							$-a_{25,7,2}$	$-a_{25,8,2}$	$-a_{25,9,2}$	$-a_{25,10,2}$	$-a_{25,11,2}$	$-a_{25,12,2}$	$-a_{25,13,2}$	$-a_{25,14,2}$						
2	Corn T.	P_{61}	$b_{26,2}$					$a_{26,5,2}$	$a_{26,6,2}$	$-a_{26,7,2}$	$-a_{26,8,2}$	$-a_{26,9,2}$	$-a_{26,10,2}$	$-a_{26,11,2}$	$-a_{26,12,2}$	$-a_{26,13,2}$	$-a_{26,14,2}$						
2	Livestock space	P_{62}	$b_{27,2}$					$a_{27,5,2}$	$a_{27,6,2}$														
2	Livestock equipment	P_{63}	$b_{28,2}$		$-a_{28,2,2}$		$-a_{28,4,2}$	$a_{28,5,2}$															
2	Labor	P_{64}	$b_{29,2}$					$a_{29,5,2}$	$a_{29,6,2}$	$a_{29,7,2}$		$a_{29,9,2}$	$a_{29,10,2}$	$a_{29,11,2}$	$a_{29,12,2}$	$a_{29,13,2}$	$a_{29,14,2}$	29,15,2	29,16,2	$a_{29,17,2}$	$a_{29,18,2}$		
2	Capital rationing	P_{65}	$b_{30,2}$																				
1	$z^I_{jk}-d^I_{jk}$	P_{66}	0	$z^I_1-d^I_1$	$z^I_{2,0}-d^I_{2,0}$									......	$z^I_{jk}-d^I_{jk}$	......							
1	$z^T_{jk}-d^T_{jk}$	P_{67}	0	$z^T_1-d^T_1$	$z^T_{2,0}-d^T_{2,0}$										$z^T_{jk}-d^T_{jk}$								

							$d^T_{23,2}$			$-d^T_{26,2}$			$d^T_{29,2}$			$d^T_{32,2}$	$d^L_{33,0}$	$d^L_{34,1}$	$d^L_{35,2}$	
2	$COM_{1,2,2}$ P_{17}	$COM_{2,2,2}$ P_{18}	Corn buying$^T_0$ P_{19}	Corn buying$^T_1$ P_{20}	Corn buying$^T_1$ P_{21}	Corn selling$^T_1$ P_{22}	Corn selling$^T_2$ P_{23}	Capital borrowing$^T_0$ P_{24}	Capital borrowing$^T_1$ P_{25}	Capital borrowing$^T_2$ P_{26}	Capital selling$^T_0$ P_{27}	Capital selling$^T_1$ P_{28}	Capital selling$^T_2$ P_{29}	Hay transfer$^T_1$ P_{30}	Hay transfer$^T_2$ P_{31}	Hay selling^T P_{32}	Corn selling^L P_{33}	Corn selling^L P_{34}	Corn selling^L P_{35}	P_{16} .....
			$a_{3,19,0}=1.24$					$-a_{3,24,0}=-1$			$a_{3,27,0}$		1							
														$a_{4,30,0}=1$						
																	$a_{5,33,0}$			
			$-a_{6,19,0}=1$																	
								$a_{10,24,0}=1$												Disposal activities
				$a_{13,20,1}=1.24$		$-a_{13,22,1}=-1.14$		$a_{13,24,1}>1$	$-a_{13,25,1}=-1$		$-a_{13,27,1}$	$a_{13,28,1}$								or
														$-a_{14,30,1}=-1$	$a_{14,31,1}=1$					identity
																		$a_{15,33,1}$		matrix
				$-a_{16,20,1}=-1$		$a_{16,22,1}=1$														
									$a_{20,25,1}=1$											
2	$a_{21,17,2}$	$a_{21,18,2}$																		
2	$\pm a_{22,17,2}$	$\pm a_{22,18,2}$										$-a_{22,28,2}$	$a_{22,29,2}$							
2	$a_{23,17,2}$	$a_{23,18,2}$			$a_{23,21,2}=1.24$		$-a_{23,23,2}=-1.14$		$a_{23,25,2}$ 1	$-a_{23,26,2}=-1$										
2	$-a_{24,17,2}$	$-a_{24,18,2}$													$-a_{24,31,2}=-1$	$a_{24,32,2}$				
																			$a_{25,35,2}$	
					$-a_{26,21,2}=-1$		$a_{26,23,2}=1$													
2	$a_{29,17,2}$	$a_{29,18,2}$																		
										$a_{30,26,2}=1$										
						......	$z_i - c_i$	......											$z^L_{35,2}-c^L_{35,2}$	
						......	$z_i - c_i$	......											$z^T_{35,2}-c^T_{35,2}$	

1. Restrictions

The tenant's restrictions are the same as those in the owner-operator model. The landlord has two restrictions in each year: capital and corn.

In a share-rented farm, capital expense is shared in a given proportion between landlord and tenant. Hence the need for two capital restrictions each year. The landlord's capital restrictions are $b_{2,0}$, $b_{12,1}$ and $b_{22,2}$.

In a rented farm also crops are shared in a specific ration. Hence a new corn restriction for the landlord is introduced, $b_{5,0}$, $b_{15,1}$ and $b_{22,2}$ for the three-year period covered by the model. Oats is planted and harvested within a given year, however. The crop activities carry a negative coefficient in the landlord's capital row (as well as in the tenant's) because oats is expressed in corn equivalent. The coefficient indicates the amount received by the tenant as a share of that crop.

2. Activities

The activities P_1 to P_{32} are tenant's activities and P_{33} to P_{35} landlord's activities.[1] As in the owner-operator farm model, returns from crops are not realized until transferred to a corn selling activity. In this model also returns forthcoming to the landlord from his share of crops are not realized until the corn is marketed through corn selling $^{L}_{0}$, P_{33}, corn selling $^{L}_{1}$, P_{34}, corn selling $^{L}_{2}$, P_{35}.

Returns of the landlord from hay or meadow activities are not realized through a selling activity. The reason is that the landlord does

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[1] A superscript L or T is used to indicate the landlord or tenant's activities.

not share in the product but rather receives a rental payment in cash. The cash payment in each year is credited to his capital row, if that payment is greater than the landlord's expenses in the other two crops included in the rotation, i.e., corn and oats, then the rotation activity will have a negative coefficient in the landlord's capital restriction row. If the expenses are greater than the cash rental, the coefficient will be positive, because the activity then "consumes" landlord capital. Hence, the $\pm$ sign in all the crop activities coefficients corresponding to landlord's capital in Figure 5.[1]

It can be noticed that all livestock activities have only zero coefficients in the rows corresponding to the landlord's restrictions. The reason is that this model follows the customary crop share-lease of the Midwest; the lease does not provide for sharing of costs and returns in livestock enterprises. The tenant bears all the expenses incurred by those enterprises and also receives all the returns. But the model could be adapted to other type of leasing arrangement such as a livestock lease. It would only be a matter of estimating the coefficients for landlord and tenant and including them in the model.

3. <u>Prices and the criterion row</u>

The landlord price row, d^L_{jk}, has only three positive coefficients corresponding to the three corn selling activities, P_{33}, P_{34} and P_{35}. These three prices $d^L_{33,0}$, $d^L_{34,1}$ and $d^L_{35,2}$ are discounted to present value

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[1] An alternative way to credit the landolord with the cash rental returns is by including their discounted values in the landlord's price row d^L_{jk}.

as seen above.

The feature which makes this model differ most from the precedent one is the inclusion of two criterion rows instead of a unique one as is the general case in models employing the simplex method. The landlord's criterion row is $z^L_{jk} - d^L_{jk}$ and the tenant's is $z^T_{jk} - d^T_{jk}$ where z_{jk} is as usual the opportunity cost and d_{jk} the gross or market price.

These two functions can be maximized separately to obtain an optimum feasible solution for both the landlord and the tenant.[1] These will provide the means to test hypotheses regarding efficiency of alternative tenure systems and to isolate tenure factors causing dissociations of benefits and costs.

F. A Short-Term Dynamic Model for a Crop-Share Farm

In figure 6 a 2-year dynamic linear programming model for a crop-share rented farm is presented. As it can be readily seen the logic and mechanics of this model does not differ greatly from the one presented above. The dissimilarities arise rather from the economic interpretations of activities and coefficients,

1. Single crop activities

Contrariwise to the ones above, this model does not have any crop rotations activities. The reason is that a tenant having a short planning horizon does not plan on a long-term basis. Each year he chooses single crops which he things will maximize his returns. Hence, the model uses

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[1]As long as there is an optimum feasible solution.

Figure 6. A two-year dynamic programming model for a crop-share rented farm

			$d^L_{jk} \longrightarrow$	+M						
			$d^T_{jk} \longrightarrow$	+M		$d^T_{3,1}$	$d^T_{4,1}$			
Year	Resource used or activity produced	P_0	Supply, remainder or output	Family living P_1	$Hogs_0$ P_2	$Hogs_{0,1}$ P_3	$Hogs_{1,1}$ P_4	$C_{1,1,0}$ P_5	$C_{2,1,0}$ P_6	$C_{1,2,0}$ P_7
0	Land	P_{33}	$b_{1,0}$					$a_{1,5,0}=1$	$a_{1,6,0}=1$	$a_{1,7,0}=1$
0	Capital L.	P_{34}	$b_{2,0}$					$a_{2,5,0}$	$a_{2,6,0}$	$a_{2,7,0}$
0	Capital T.	P_{35}	$b_{3,0}$	$a_{3,1,0}=1$	$a_{3,2,0}$			$a_{3,5,0}$	$a_{3,6,0}$	$a_{3,7,0}$
0	Hay	P_{36}	$b_{4,0}$		$a_{4,2,0}$					
0	Corn L.	P_{37}	$b_{5,0}$							
0	Corn T.	P_{38}	$b_{6,0}$		$a_{6,2,0}$					
0	Livestock space	P_{39}	$b_{7,0}$		$a_{7,2,0}$					
0	Labor	P_{40}	$b_{8,0}$		$a_{8,2,0}$			$a_{8,5,0}$	$a_{8,6,0}$	$a_{8,7,0}$
	Family living	P_{41}	b_9	$a_{9,1,0}$						
0	Capital rationing	P_{42}	$b_{10,0}$		$a_{10,2,0}$					
1	Land	P_{43}	$b_{11,1}$							
1	Capital landlord	P_{44}	$b_{12,1}$							
1	Capital tenant	P_{45}	$b_{13,1}$	$a_{13,1,1}=1$	$-a_{13,2,1}$	$a_{13,3,1}$	$a_{13,4,1}$			
1	Hay	P_{46}	$b_{14,1}$			$a_{14,3,1}$	$a_{14,4,1}$			
1	Corn landlord	P_{47}	$b_{15,1}$					$-a_{15,5,1}$	$-a_{15,6,1}$	$-a_{15,7,1}$
1	Corn tenant	P_{48}	$b_{16,1}$			$a_{16,3,1}$	$a_{16,4,1}$	$-a_{16,5,1}$	$-a_{16,6,1}$	$-a_{16,7,1}$
1	Livestock space	P_{49}	$b_{17,1}$			$a_{17,3,1}$	$a_{17,4,1}$			
1	Livestock equipment	P_{50}	$b_{18,1}$		$-a_{18,2,1}$	$a_{18,3,1}$				
1	Labor	P_{51}	$b_{19,1}$			$a_{19,3,1}$	$a_{19,4,1}$			
1	Capital rationing	P_{52}	$b_{20,1}$							
2	$z^L_{jk} - d^L_{jk}$	P_{53}	$b_{21,2}$	$z^L_1 - d^L_1$	$z^L_{2,0} - d^L_{2,0}$	....				
2	$z^T_{jk} - d^T_{jk}$	P_{54}	$b_{22,2}$	$z^T_1 - d^T_1$	$z^T_{2,0} - d^T_{2,0}$	....				

			$d^L_{9,2}$	$d^L_{9,2}$							
			$d^T_{9,2}$	$d^T_{10,2}$							
Year	Resource used or activity produced	$C_{2,2,0}$ P_8	$C_{1,1,1}$ P_9	$C_{2,1,1}$ P_{10}	$O_{1,1,0}$ P_{11}	$O_{2,1,0}$ P_{12}	$O_{1,2,0}$ P_{13}	$O_{2,2,0}$ P_{14}	$O_{1,1,1}$ P_{15}	$O_{2,1,1}$ P_{16}	$M_{1,1}$ P_{17}
0	Land	$a_{1,8,0}=1$			$a_{1,11,0}$ 1	$a_{1,12,0}$ 1	$a_{1,13,0}$ 1	$a_{1,14,0}=1$			$a_{1,17}$
0	Capital L.	$a_{2,8,0}$			$a_{2,11,0}$	$a_{2,12,0}$	$a_{2,13,0}$	$a_{2,14,0}$			$-a_{2,17}$
0	Capital T.	3,8,0			$a_{3,11,0}$	$a_{3,12,0}$	$a_{3,13,0}$	$a_{3,14,0}$			$a_{3,17}$
0	Hay										$-a_{4,17}$
0	Corn L.				$-a_{5,11,0}$	$-a_{5,12,0}$	$-a_{5,13,0}$	$-a_{5,14,0}$			
0	Corn T.				$-a_{6,11,0}$	$-a_{6,12,0}$	$-a_{6,13,0}$	$-a_{6,14,0}$			
0	Livestock space										
0	Labor	$a_{8,8,0}$			$a_{8,11,0}$	$a_{8,12,0}$	$a_{8,13,0}$	$a_{8,14,0}$			$a_{8,17}$
	Family living										
0	Capital rationing										
1	Land		$a_{11,9,1}=1$	$a_{11,10,1}=1$					$a_{11,15,1}=1$	$a_{11,16,1}=1$	
1	Capital landlord		$a_{12,9,1}$	$a_{12,10,1}$					$a_{12,15,1}=1$	$a_{12,16,1}=1$	
1	Capital tenant		$a_{13,9,1}$	$a_{13,10,1}$					$a_{13,15,1}=1$	$a_{13,16,1}=1$	
1	Hay										
1	Corn landlord	$-a_{15,8,1}$							$-a_{15,15,1}$	$-a_{15,16,1}$	
1	Corn tenant	16,8,1							$-a_{16,15,1}$	$-a_{16,16,1}$	
1	Livestock space										
1	Livestock equipment										
1	Labor		$a_{19,9,1}$	$a_{19,10,1}$					$a_{19,15,1}$	$a_{19,16,1}$	
1	Capital rationing										
2	$z^L_{jk} - d^L_{jk}$								... $z^L_{jk} - d^L_{jk}$		
2	$z^T_{jk} - d^T_{jk}$								... $z^T_{jk} - d_{jk}$		

	$M_{1,1,0}$ P_{17}	$M_{2,1,0}$ P_{18}	$M_{1,1,1}$ P_{19}	$M_{2,1,1}$ P_{20}	Corn buying$^T_0$ P_{21}	Corn buying$^T_1$ P_{22}	Corn selling$^T_0$ P_{23}	Corn selling$^T_1$ P_{24}	Capital borrowing$^T_0$ P_{25}	$-d^T_{26,2}$ Capital borrowing$^T_1$ P_{26}	Capital selling$^L_0$ P_{27}	$d^T_{28,2}$ Capital selling$^T_1$ P_{28}	Hay selling$^T_0$ P_{29}	Hay selling$^T_1$ P_{30}	$d^L_{31,0}$ Corn selling$^L_0$ P_{31}	$d^L_{32,1}$ Corn selling$^L_1$ P_{32}	Land disposal P_{33} .....
	$a_{1,17,0}=1$	$a_{1,18,0}=1$								1							1
	$-a_{2,17,0}$	$-a_{2,18,0}$															
	$a_{3,17,0}$	$a_{3,18,0}$			$a_{3,21,0}=1.24$		$-a_{3,23,0}=-1.14$		$-a_{3,25,0}=-1$		$a_{3,27,0}=1$		$-a_{3,29,0}=-6.0$				
	$-a_{4,17,0}$	$-a_{4,18,0}$											$a_{4,29,0}=1$				
															$a_{5,31,0}=1$		
					$-a_{6,21,0}=-1$		$a_{6,23,0}=1$										
	$a_{8,17,0}$	$a_{8,18,0}$															
									$a_{10,25,0}=1$								
16,1=1			$a_{11,19,1}=1$	$a_{11,20,1}=1$													
16,1=1			$-a_{12,19,1}$	$-a_{12,20,1}$													
16,1=1			$a_{13,19,1}$	$a_{13,20,1}$		$a_{13,22}=1.24$		$-a_{13,24,1}=-1.14$	$a_{13,25,1}$	$-a_{13,26,1}=-1$	$-a_{13,27,1}=-1.05$	$a_{13,28,1}=1$		$-a_{13,30,1}=-6.0$			
			$-a_{14,19,1}$	$-a_{14,20,1}$										$a_{14,30,1}=1$			
16,1																$a_{15,32,0}=1$	
16,1						$-a_{16,22,1}=-1$		$a_{16,24,1}=1$									
16,1			$a_{19,19,1}$	$a_{19,20,1}$													
										$a_{20,26,1}=1$							

....$z^L_{32,1} - d^L_{32,1}$....
....$z^T_{32,1} - d_{32,1}$....

single crops as activities.

For example, a unit of $C_{1,1,0}$, that is P_5, represents an acre of corn grown in year k=0 at a low level of fertilization and only using contouring as a conservation practice. It can be noticed that the coefficients in the two corn rows of that first year are equal to zero. This means that corn produced that year is not accounted until the beginning of the following because it can neither be fed or sold until then. Consequently, landlord and tenant's second year corn coefficients $-a_{15,5,1}$ and $-a_{16,5,1}$ are negative.

The above qualification does not apply to oats and meadow activities. Oats and hay can be fed and sold within the same year it is sown. Therefore, the corn rows of the first year, k=0, carry positive coefficients in the oats activities.[1] Meadow activities as well carry positive coefficients in the hay row of the first year.

Another point that should be stressed is that there are no second-year activities start at a high level of conservation, i.e., with terracing. It is then assumed that a farmer expecting to leave the farm at the end of the year does not care to make any investment in terracing. In economic terms this means that the present value of expected returns is equal to zero under this assumption.

It is also noted that costs incurred by terracing are all charged to the tenant within the period covered by the lease. In the case of longer term leasing arrangements these costs can be spread over a larger number of years becoming thus less onerous to the tenant.

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[1]Oats output is expressed in corn equivalent.

IV. APPLICATION OF THE MODEL TO A CASE SITUATION

The purpose of this chapter is to describe the empirical situation to which the dynamic models presented above will be applied. Details will be given with regard to the farm selected for this study and the different resource restrictions under which profits will be maximized.

A. Description of the Farm and Its Location

The farm selected for study as representative of the Iowa section of the MINK study is located in Fremont County, southwestern Iowa. It is 260 acres in size, of which 220 acres have field crops and pastures. The remaining 40 acres include the farmstead, buildings, roads, fences, wasteland and timber.

The farm is located within the Marshall soil association which occupies nearly level to gently sloping ridges and rolling lands of 2 to 14 per cent slopes. Marshall soils are "medium textures, moderately permeable and well drained. Control of sheet and gully erosion is a major soil management problem. Level terraces are used to good advantage on these soils" (38,p. 2). Under good management these soils are considered very productive within the state of Iowa.

B. Descriptions of the Resource and Institutional Restrictions

1. Land restriction

Since the land of the farm has different characteristics with regard to slope and productivity, it has been divided into two groups for the purpose of this study: Land A and Land B.

Land A has 60 acres with slope less than 5 percent and Land B has 160 acres with a slope from 8 to 12 percent. Table 7 shows the different types of soils found in the farm. The level of fertility is considered low medium in P_2O_5 and high in K. It is assumed that land previously has been under a crop rotation which included one or two years of meadow.

Table 7. Soil characteristics of farm in Fremont County, Iowa

Soil type	Total acres	Acres with slope		Percent of total
		Less than 4 percent	From 8 to 12 percent	
Marshall silt loam	49.5	49.5		22.5
Judson silt loam	10.5	10.5		4.8
Marshall silt loam	160.0		160.0	

Source: Soil Conservation District, Fremont County, Iowa

2. Capital and machinery

It is assumed that the farm in question has machinery as shown in Table 8. However, a custom operator is hired to bale hay. In this machinery inventory specialized livestock equipment is not included. It must be purchased by the operator.

The levels of capital assumed for owner-operator and landlord and tenant in a share-rented farm are given in Table 9. This is not only operating capital but it does include the amount required for family consumption in case of the owner-operator and tenant.

Table 8. Farm machinery

Machine type	New value dollars	Duration years	Annual cost dollars
Tractor, 30-40 belt HP	3,090.00	10	309.00
Plow, 3 14"	434.00	15	28.93
Tandem disc, 10"	410.00	15	27.33
Harrow, 4 section	142.00	15	9.47
Corn planter, 2 row	276.00	15	18.40
Cultivator	294.00	15	19.60
Wagons, 2	400.00	12	33.33
Manure spreader	493.00	15	32.87
Sprayer	195.00	15	13.00
Pick-up truck, ½ ton	1,840.00	10	184.00
Corn picker, 2	2,191.00	15	82.67
Power mower	366.00	14	26.14
Endgate seeder	80.00	15	5.33
Rotary hoe	433.00	15	28.87
Combine	1,790.00	15	119.33
	$12,434.00		$938.27

Table 9. Operating capital on owner-operated and share-rented farms

Owner-operator	$12,460
Crop-share-cash lease	
Landlord	3,460
Tenant	8,250

Source: MINK study, Iowa section

It can be noted that the level of capital for the owner-operator is not equal to the sum of the capital resources contributed by both landlord and tenant in a rented farm.

3. Labor supply

Labor resources in this study is understood as direct labor input of the operator which includes "time spent in growing, harvesting, storing and selling crops or time spent in feeding, caring for and marketing livestock products" (22, p, 9). The family labor is used only for indirect labor input excepting some extra days in May, June and July when the operator is assumed to receive some help in the planting and cultivation of crops. Labor availability in January, February, July, August, September, October, November and December is considered adequate or not limiting. The rest of the months of the year are grouped together in order to avoid computational complexities. This can be justified because labor operations in many cases can be shifted over time or postponed. The total labor available is given in Table 10.

Table 10. Labor supply of operator in hours of direct labor input

Month	Working days	Hours/day	Total hours
March-April	52	8½	442
May-June	62[a]	10	650

[a]Includes 13 days furnished by the operator's family

4. Building space restrictions

Hay and grain storage capacity is assumed to be adequate. One 2-litter hog unit is defined as 50 square feet of building space. It is assumed that 20 of such units are available on the farm. Cattle units are to a certain extent substitutable for hog units. The requirements of different hog and cattle enterprises are presented in Table 11. Yearling steers do not require any building space.

Table 11. Building space requirements of livestock enterprises.

Name of enterprise	Steer calves on pasture	Steer calves drylot feed	Hogs (1:0) spring	Hogs (1:1) spr.-fall
	0.4	0.6	0.75	1.0

5. Management

The profit of a firm depends on the efficiency of operation and ultimately on the managerial ability of the operator. The manager or entrepreneur is the person who combines the different resources and chooses between alternative production plans. There can be, of course, different levels of managerial capacity. For the purposes of this study all plans are computed assuming an average capacity in the person of the farm operator. Although a precise definition cannot be given we understand by "average" manager one who ordinarily uses the following set of practices (22, p. 101).

1) Use of recommended varieties

2) Weed control included only limited use of herbicide

3) Oats and corn seed treated; legumes inoculated; corn borer and grasshopper controlled

4) Most operations within allowable range of timeliness, but not necessarily at the optimum point

5) Planting rates per acre approximate the following: corn - 12,000 stalks, oats - 1½ bushels, soybeans - 1 bushel, alfalfa brome mix - 15 pounds

6) Optimum planting depth used.

Besides, an "average" manager will possess some technical education, some experience of farming and will take part, although not assuming an outstanding role, in the activities of farmers associations and other community organizations.

6. Household consumption

It is assumed that the household is composed of the operator, his wife and two or three children. The living costs, including also health insurance and income and property taxes, amount to $4,560 per year for the owner-operator and $3,520 for the share-tenant. The difference between the two amounts is due to real estate taxes and crop and building insurance which are charged only to the owner-operator as shown on Appendix A.

7. Leasing restrictions

Although the form of the lease is not exactly a restriction it is included here because up to a certain extent the lease affects some of the restrictions such as capital and corn - it adds extra capital and corn rows to the input and output matrix for the landlord every year. The typical crop-share-cash lease of the Middle West shares costs and returns as shown on Table 12.

Table 12. Typical crop-share-cash lease of the Middle West

Item	Receipts or expenses	
	Tenant share (%)	Landlord share (%)
Corn	50	50
Soybeans	50	50
Oats	60	40
Fertilizer and seed expenses[a]	50	50
Real state expenses	0	100
Operating expenses	100	0
Feeder cattle and hogs	100	0
Labor, including hired	100	0

[a]Landlord furnishes all of the grass and legume seed while tenant furnishes all of the seed oats. Landlord receives a cash rental on hay of \$13 in Land A and of \$12 in Land B.

C. Prices

Prices used in this study try to maintain the historical price relationships among inputs and outputs existing in the years previous to 1960. The reason is that the agricultural entrepreneur is assumed to make his long term plan in year 1960. The mean value of 1955-59 prices was used for programming the different farm plans. These prices are given in Table 13.

The mean value of yearly prices is a relatively simple model of price expectations for the entrepreneur. It was used in this study because in the period considered relevant input and output prices did not

Table 13. Mean value of 1955-59 prices

Input or output and unit	Price in dollars
Crops:	
Corn per bushel (buying)	1.24
Corn per bushel (selling)	1.14
Oats per bushel	.63
Soybeans per bushel	2.16
Hay per ton	6.00
Feeder calves:	
October calves per cwt.	27.00
Feeder yearling steers:	
November medium per cwt.	19.00
October choice per cwt.	25.00
Slaughter cattle:	
April medium per cwt.	22.00
June choice per cwt.	24.00
August choice per cwt.	25.00
September choice per cwt.	25.00
October choice per cwt.	25.00
Hogs:	
May gilts and barrows per cwt.	17.00
October and November gilts and barrows per cwt.	15.00
January sows per cwt.	14.40
August sows per cwt.	15.50
Fertilizer:	
Nitrogen per pound	.13
Phosphate per pound	.09
Potash per pound	.05

Source: (21) and (39).

vary such as to warrant the use of a more elaborated model. Besides, the distorting effect of livestock price cycles on the relationships between livestock prices and other prices seems to have been eliminated because a complete livestock price cycle appears to be included in the five years considered.

D. Crop Enterprises

The present section endeavors to give a brief description of the activities used for programming the different farm plans. The two long-term models, i.e., those for owner-operator and crop-share operator covering a six-year period, permit the farmer to choose each year between different crop rotations. The short-term model, i.e., the two-year model for a crop-share tenant or landlord, has single crops as activities instead of crop rotations.

The extrepreneur chooses every year the crops which he thinks will maximize his returns given his capital and other resources, price and yield expectations, risk perference, consumption patterns, etc. If the latter factors are maintained at a fixed level, the effect of various leasing arrangements on the choice of crops and ultimately on total returns can be investigated.

1. Long term rotations

The selection of rotations to include among the activities in the long-term models was based on previous studies for the same type of soil (13, 15) and on information coming from soil scientists and agronomists. In Table 14 the yields estimates for rotations planted on Land A and in

Table 14. Estimated crop-rotation yields for various levels of conservation and fertilization in Land A and Land B

	Marshall silt loam			Land A[a]			Slope: 1-4%		
Practices:	No conservation			Contouring			Terracing		
Fertilizers:	No	Low	High	No	Low	High	No	Low	High
Rotation									
Corn$_1$	50[b]	55[b]	69[b]	55	60	74	55	60	74
Oats	30	35	42	30	35	42	33	38	45
Meadow$_1$[c]	2.2	2.4	3.0	2.2	2.4	3.0	2.2	2.4	3.0
Corn$_1$	50	55	69	55	60	74	55	60	74
Corn$_2$	45	50	68	50	55	72	50	55	72
Oats	30	35	42	30	35	42	33	38	45
Meadow$_1$[c]	2.2	2.4	3.0	2.2	2.4	3.0	2.2	2.4	3.0
Meadow$_2$	2.2	2.5	3.2	2.2	2.5	3.2	2.2	2.5	3.2
Corn$_1$	50	55	69	55	60	74	55	60	74
Soybeans	20	24	26	22	25	27	23	26	28
Corn$_1$	44	49	68	49	54	71	49	54	71
Oats	30	35	42	30	35	42	33	38	45
Meadow	2.2	2.4	3.0	2.2	2.4	3,0	2.2	2.4	3.0
Corn$_1$	50	55	69	55	60	74	55	60	74
Corn$_2$	43	48	68	48	53	72	48	53	72
Oats	30	35	42	30	35	42	33	38	45
Meadow	2.2	2.4	3.0	2.2	2.4	3.0	2.2	2.4	3.0

[a]Land - Marshall - Monona in Walnut Township, Fremont County, Iowa.

[b]Yield of corn, oats, soybeans in bushels/acre; meadow is in tons/acre.

[c]Meadow, M_1, is first year alfalfa - brome mixture, 3 cuttings.

Table 14 (Continued)

	Marshall silt loam			Land A[a]			Slope: 1-4%		
Practices:	No conservation			Contouring			Terracing		
Fertilizers:	No	Low	High	No	Low	High	No	Low	High
Corn$_1$[d]	43	48	63	45	50	65	48	53	68
Corn$_2$	40	45	63	42	47	65	45	50	68
Corn$_3$	37	42	63	39	44	65	42	47	68
Corn$_{4-10}$	30	35	63	32	37	65	35	40	68
				Land B[a]		Slope: 8-12%			
Corn$_1$	36[b]	41[b]	54[b]	39	44	57	42	47	60
Oats	20	25	32	21	26	33	24	29	36
Meadow$_1$[c]	2.0[c]	2.2	2.7	2.0	2.2	2.7	2.1	2.3	2.8
Corn$_1$	36	41	54	39	44	57	42	47	60
Corn$_2$	33	38	50	36	41	53	39	44	58
Oats	20	25	32	21	26	33	24	29	36
Meadow$_1$[c]	2.0	2.2	2.7	2.0	2.2	2.7	2.1	2.3	2.8
Meadow$_2$	2.0	2.2	2.8	2.0	2.2	2.8	2.1	2.3	3.0
Corn$_1$	36	41	54	39	44	57	42	47	60
Corn$_2$	30	35	48	33	38	52	38	42	57
Oats	20	25	32	21	26	33	24	29	36
Meadow	2.0	2.2	2.7	2.0	2.2	2.7	2.1	2.3	2.8

Source: Frank F. Riecken, W. F. Shrader, and David F. Slusher, Agronomy Department, Iowa State University. Private communication. Feb. 22, 1960

[d]Assumption is that fertility level is low-medium in P_2O_5, high in K; rotation has been corn, corn, oats, meadow, meadow.

Table 15 the ones for rotations grown on Land B are given.[1]

In Land A there are five alternatives: COM,CCOMM, CSbCOM, CCOM, and CCC.[2] In Land B there is a choice of three rotations: COM, CCOMM, and CCOM.

The assumptions under which the yields were estimated are several. The fertility level in year k=0 is considered low-medium in P_2O_5 and high in K. It is assumed that the farm land has been previously rotated with CCOMM, CCOM or COM. That is, the rotations used on that farm included at lease one third of meadow. Low-medium fertility practices were had in these rotations. It is further assumed, that the meadow is alfalfa-brome mixture and that it permits three annual cuttings.

Three levels of fertilization were used. The first one assumes no fertilization practices.. The second one represents a low level of fertilization that may correspond approximately to the one obtained by manure spreading as practiced on some farms. The third one, a high level of fertilization, employs commercial fertilizers as shown in Table 15 for Land A and B respectively. In the high level of fertilization it is further assumed that besides the nitrogen and phosphate quantities shown in the tables, a rate of 10 pounds of K_2O us required per acre.

Three levels of conservation are considered in this study. The first

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[1]For a description of Land A and Land B we refer back to this same chapter, section A.

[2]As explained above the meaning of the symbols are as follows: C is corn, O is oats, M is meadow and Sb is soybeans. For instance CCC stands for continuous corn and COM for a 3-hear rotation of corn, oats and meadow.

Table 15. Pounds per acre of available nutrients supplied by commercial fertilizers for different rotations, conservation and fertilization levels

	Marshall silt loam			Land A[a,b]			Slope: 2-5%		
Practices:	No conservation			Contouring			Terracing		
Fertilizers:	No N P	Low N P	High N P	No N P	Low N P	High N P	No N P	Low N P	High N P
Corn[c]		5	5+10		5	5+10		5	5+10
Oats		0+10	10+0		0+10	10+0		0+10	10+0
Meadow			0+10			0+10			0+10
Corn[c]		5	5+10		5	5+10		5	5+10
Corn		5	50+10		5	50+10		5	50+10
Oats		0+10	10+0		0+10	10+0		0+10	10+0
Meadow			0+10			0+10			0+10
Meadow			0+10			0+10			0+10
Corn[c]		5	5+10		5	5+10			5+10
Soybeans									
Corn		5	35+10		5	35+10		5	35+10
Oats		0+10	10+0		0+10	10+0		0+10	10+0
Meadow			0+10			0+10			0+10
Corn[c]		5	5+10		5	5+10		5	5+10
Corn		5	50+10		5	50+10		5	50+10
Oats		0+10	10+0		0+10	10+0		0+10	10+0
Meadow			0+10			0+10			0+10

[a]Low-medium fertilization practices in 1958 and 1959.

[b]10 pounds K_2O on all high corn.

[c]Assume previous rotation is the same as the one used.

Table 15 (Continued)

	Marshall silt loam			Land A[a,b]			Slope: 2-5%		
Practices:	No conservation			Contouring			Terracing		
Fertilizers	No N P	Low N P	High N ½	No N P	Low N P	High N P	No N P	Low N P	High N P
Corn 1960[d]		5	35+10		5	35+10		5	35+10
Corn 1961		5	50+10		5	50+10		5	50+10
Corn 1962		5	50+10		5	50+10		5	50+10
Corn 1963-1970		5	50+10		5	50+10		5	50+10
	Marshall silt loam			Land B[a,b]			Slope: 9-14%		
Corn[c]		5	5+25		5	5+25		5	5+25
Oats		0+10	10+10		0+10	10+10		0+10	10+10
Meadow									
Corn[c]		5	5+25		5	5+25		5	5+25
Corn		5	60+15		5	60+15		5	60+15
Oats		0+10	10+10		0+10	10+10		0+10	10+10
Meadow									
Meadow			0+10			0+10			0+10
Corn[c]		5	5+25		5	5+25		5	5+25
Corn		5	60+15		5	60+15		5	60+15
Oats		0+10	10+10		0+10	10+10		0+10	10+10
Meadow									

Source: Private communication by John T. Pesek and Frank F. Riecken, Agronomy Department, Iowa State University, Feb. 22, 1960

[d]Assume that Corn, Corn, Oats$_{2-6}$ and Corn, Corn, Corn, follow Corn, Corn, Oats, Meadow, Meadow, or Corn, Oats, Meadow.

one uses no conservation practices. The second one uses contouring for all grain crops. The third one uses contouring and also terraces. It is assumed that in years previous to the one considered in our study, i.e., 1960, no terraces were built on the farm.

2. Erosion effect on yields

The maximum erosion rate compatible with the maintenance of the soil fertility is considered to be 5 tons of soil loss per acre. Above that level of erosion, soil fertility is depleted over time causing a decrease in yields. Only some of the rotations included in this study meet the maximim permissible erosion requirement. Table 16 shows the percentage yield decrease per acre in a six-year period for different rotations at different levels of conservation in the soil area considered in this study.

According to the table those rotations which during the six-year period have a 0 percent decrease in yields have a yearly soil loss of 5 tons per acre or less. It can be seen that most of the eligible rotations in Land A meet the maximum soil erosion requirement. Rotations using Land B cause more erosion unless a high level of conservation practices is employed.

In agreement with the above, the output coefficients used in programming the different plans have been adjusted for the decrease in yield due to soil erosion.[1]

3. Single crops in the short-term model

A tenant with a limited planning horizon will not plan for the future

[1]For sake of simplicity the rate of erosion was presumed to be a linear function of time.

Table 16. Percentage of per acre yield decrease in a 6-year period due to soil erosion

Crop Rotation	Land A Conservation None	Land A Conservation Contour	Land A Conservation Terrace	Land B Conservation None	Land B Conservation Contour	Land B Conservation Terrace
COM	0	0	0	1	0	0
CCOMM	0	0	0	2	2	0
CCOM	0	0	0	3	3	0
CSbCOM	1	0	0	5	4	3
CCC	2	k	0	6	5	4

Source: David F. Slusher, W. D. Shrader and Frank F. Reicken, Agronomy Department, Iowa State University. Private Communication. 1960.

in terms of crop rotations extended throughout a number of years but rather in terms of yearly crops. The reason is that he does not know whether or not he will remain on the farm and consequently obtain the returns associated with crop rotations. Consequently, yield estimates for a farm under a short-term leasing arrangement should be given for single crops rather than for rotations contrariwise to those for an owner-operated farm or for a rented farm with a long term lease.

The objective of this study is to compare returns from a long term (six years) share-rented farm and those from a farm successively rented under three short-term leases of two years each. Therefore, there should be three sets of yield estimates for each of the two-year periods covered by the three leasing arrangements.

In Table 18 of Appendix B the per acre yield estimates for different crops of first and second year (years k=0 and 1) are presented.[1] It can

[1]The yield estimates of this table and the following ones have been adjusted for soil erosion.

be noticed that no yield estimates are given for second year corn, C_1, at a high level of conservation (terracing). As expressed above the one-year planning horizon inhibits the tenant from investing in terraces.

Table 19 in Appendix B provides the per acre yield estimates for different crop combinations of third and fourth year during the second of the three successive leases. Yield estimates for the last two years, which is the duration of the third consecutive lease, are given in Table 20 in Appendix B.

Tables 21, 22 and 23 in Appendix B present as well the fertilizer rates applied to the different crops during the three successive lease periods.

4. Labor requirements

The requirements of direct labor input of hours per day for different crops are given in Table 24.

Table 24. Hours per day of direct labor input required for different crops

Crop	Dec.-Jan. Feb.	March - April	May-June	July-August	Sept.-Oct. Nov.
1st year corn	.0234	1.0015	2.6005	.2811	1.9504
2nd year corn	.0260	1.1110	2.8847	.3119	2.1635
Corn following Sb	.0247	1.0562	2.7426	.2965	2.0569
Soybeans after corn	.0368	2.4832	2.4202	.1732	.1365
Oats after corn	.2688	1.8819	.5377	.0172	.0000
Meadow[a]	.0000	.0000	.6000	.6000	.8000

Source: (22).

[a]Does not include labor input used in harvesting.

As stated before the supply of labor available in all months except March-April and May-June is considered non-limiting.

5. Capital requirements

The per acre variable production costs in dollars are given in Table 26 for different rotations in an owner-operated farm. In a crop-share rented farm variable costs are split between landlord and tenant according to the figures given in Table 25. Finally, variable costs for different yearly crops are given in Table 26.

These figures include among the variable costs the expenses on livestock equipment which is not included among the fixed costs. The reason is that specialized livestock equipment is usually purchased on a farm only when there is some enterprise which requires this equipment such as hogs or cattle.

D. Livestock Activities

In the following paragraphs a brief description of each of the six livestock activities considered in this study is offered. These activities can be divided into two groups including respectively cattle and hog enterprises. The details about capital, hay, corn and labor requirements are given in Tables 27 and 28 for each of the two groups.

As stated before an "average" level of management is assumed for the computation of input-output coefficients. Resource requirements and returns are calculated on the unit basis of one head of cattle enterprises and of litters for hog enterprises.

It is noted that in a crop-share rented farm all costs originating

Table 25. Per acre yearly variable costs in dollars of different rotations on owner-operated farms

	No conservation			Contouring			Terracing		
Fertilizer:	No	Low	High	No	Low	High	No	Low	High
COM[B]	5.98	6.546	8.026	6.092	6.659	8.139	7.489	8.056	9.539
CCOM[B]	7.013	7.638	11.157	7.158	7.783	11.309	8.61	9.23	12.76
CCOMM[B]	6.26	6.76	9.68	6.37	6.87	9.86	7.85	8.35	11.35
CSbCOM[A]	8.013	8.513	10.337	8.183	8.672	10.485	9.189	9.689	11.501
CCOM[A]	7.201	7.856	10.617	7.391	8.016	10.784	8.374	8.999	11.767
CCC[A]	9.70	10.50	18.23	9.93	10.73	18.46	10.86	11.66	19.39

Table 26. Per acre annual variable costs for different rotations on a crop-share rented farm for tenant and landlord

	No conservation			Contouring			Terracing		
Fertilizer:	No	Low	High	No	Low	High	No	Low	High
COM[B]	4.646[a]	4.954	5.759	4.717	5.026	5.831	5.431	5.739	6.547
	1.33[b]	1.592	2.267	1.375	1.633	2.308	2.058	2.317	2.992
CCOM[B]	5.763	6.113	8.001	5.858	6.208	8.103	6.612	6.954	8.857
	1.25	1.525	3.156	1.30	1.535	3.206	1.994	2.271	3.900
CCOMM[B]	5.255	5.535	7.069	5.331	5.611	7.205	6.090	6.370	7.976
	1.00	1.22	2.615	1.04	1.26	2.655	1.763	1.983	3.378
CSbCOM[A]	6.413	6.693	7.717	6.528	6.807	7.820	7.031	7.311	8.323
	1.600	1.820	2.630	1.655	1.655	2.665	2.158	2.378	3.178
CCOM[A]	5.951	6.331	7.848	6.091	6.441	7.965	6.582	6.932	8.457
	1.25	1.525	2.769	1.30	1.575	2.819	1.792	2.067	3.310
CCC[A]	1.00	1.32	4.79	1.09	1.41	4.87	1.50	1.83	5.30
	8.70	9.18	13.44	8.85	9.32	13.58	9.36	9.84	14.10

[a]Tenant

[b]Landlord

Table 27. Per unit resource requirements and returns for livestock activities

Good to choice feeder calves fed on pasture (Cattle 1)	
Purchase month	October
Market month	October
Purchase weight lbs.	430
Market weight	1,052
Average daily gain	1.72
Days on farm	360
Death loss % of purchase cost	2.5
Market price	25.00
Market revenue 1052 lbs. x 25	260.10
Gross revenue	$260.10
Annual cash expense	
Purchase cost 430 lbs. x $0.27	116.10
Protein supplement 260 x $0.045	11.70
Power and equipment	2.45
Equipment replacement	3.24
Hay harvest $4.04 per ton	3.64
Hauling .36 per cwt.	3.79
Miscellaneous (1.5% of gross revenue	3.90
	$144.82
Net revenue	$115.28
Capital requirements	
Annual cash expense - feeder stock	144.82
Equipment	15.42
1st year:	$160.24
2nd year:	$144.82
Feed requirements	
Corn (bushel)	52.00
Hay (ton)	.90
Pasture (130 AVD)	1.56
Supplement (lbs.)	260.00

Table 27 (Continued)

Good to choice feeder calves fed in dry lot (cattle 2)		
Purchase month		October
Market month		September
Purchase weight		430
Market weight		1030
Average daily gain		1.76
Days on farm		340
Death loss % of purchase cost		2.5
Market price		25.00
Market revenue - 1030 lbs. x $1.25		$254.60
Gross revenue		$254.60
Annual Cash Expense		
Purchase cost 430 lbs. x $0.27		116.10
Protein supplement 260 lbs. x $.045		11.70
Power and equipment		2.45
Equipment replacement		3.24
Hay harvest .7 x $4.04		2.83
Hauling 10.30 x .36		3.71
Miscellaneous		3.82
		$143.85
Feeder stock		
Net revenue		$110.75
Capital Requirements		
Annual cash expense		143.85
Equipment		14.67
	1st year:	$158.52
	2nd year:	$143.85
Feed Requirements		
Corn (bushels)		60.00
Hay (tons)		.70
Pasture (AVD)		-
Supplement (lbs.)		260

Table 27 (Continued)

Choice yearling steers (cattle 3)		
Purchase month		October
Market month		June
Purchase weight		621
Market weight		1121
Average daily gain		2
Days on farm		250
Death loss % or purchase cost		1
Market price		24.00
Market revenue - 1121 lbs. x .24		267.49
Gross revenue		$267.49
Annual Cash Expense		
Protein supplement 250 x .045		11.25
Purchase cost 621 x .25		155.25
Power and equipment		2.30
Equipment replacement		2.62
Hay harvest 1 x 4.04		4.04
Hauling 11.32 x .35		3.96
Miscellaneous		4.11
		$183.53
Net revenue		$ 83.96
Capital Requirements		
Equipment		14.67
Annual cash expense		183.30
	1st year:	$197.97
	2nd year:	183.30
Feed Requirements		
Corn (bushels)		55
Supplement (lbs)		250
Hay (tons)		1
Pasture (tons)		-

Table 27 (Continued)

Medium yearling steers (cattle 4)		
Purchase month		November
Market month		April-May
Purchase weight		670
Market weight		1030
Average daily gain		2
Days on farm		180
Death loss % of purchase cost		0.5
Market price		22.00
Market revenue - 1030 x .22		225.96
Gross revenue		$225.96
Annual Cash Expense		
Purchase cost 670 lbs. x .19		127.30
Protein 150 x .045		6.75
Power and equipment		3.40
Equipment replacement		3.68
Hay harvest 1.6 x 4.04		6.47
Hauling 10.30 x .35		3.60
Miscellaneous		3.39
		$154.59
Net revenue		71.37
Capital Requirements		
Equipment		18.38
Annual cash expense		154.59
	1st year:	$172.97
	2nd year:	154.59
Feed Requirements		
Corn (bushels)		37
Supplement (lbs.)		150
Hay (ton)		1.6
Pasture (30 PUD) tons of hay		0.36

Source: (15) The coefficients were adjusted after consultation with Everett Stoneberg, Extension Service, Animal Husbandry Department, Iowa State University of Science and Technology.

Table 28. Per unit resource requirements and returns for hog enterprises

Spring pigs (1:0). Average management (hogs 1)			
Number of pigs weaned per unit		7.30	
Death loss after weaning	0.10		
Replacement gilts kept	1.08		
		6.12	
6.12 pigs x 240 lbs.: 1468 x 15.00			$220.32
Sow - 350 lbs. (average) 15.50			54.25
Gross returns			$274.57
Feed Fed			
Corn (bushels)		105.446	
Hay (tons)		.018	
Pasture (29.380 PVD) tons		.352	
Protein supplement cwt.		7.192	
Annual Cash Expense			
Supplement 7.192 x 0.55		39.56	
Boar charge		2.50	
Equipment use		5.80	
Power and machinery		5.88	
Hauling		1.00	
Veterinary, electricity, miscellaneous		4.70	
Hay harvesting costs .018 x 4.04		.73	
		$60.17	
Capital coefficient 1st year			
Gilt		39.00	
Equipment (½ cost of new equipment per unit)		20.87	
Capital Coefficient 2nd year		$ 60.17	

Table 28 (Continued)

Spring and fall pigs (1:1) average management (hogs 2)		
Number of pigs weaned per unit		14.60
Death loss after weaning	0.30	
Replacement gilts kept	0.83	
		13.57
13.57 pigs of 230 lbs.		
1560 lbs. x 17.00		$265.20
1560 lbs. x 15.00		234.00
Sow - 300 lbs. (July-January x 14.40		43.20
Gross returns		$542.40
Feed Fed		
Corn (bushels)		202.824
Hay (tons)		0.031
Pasture (31.300 AVD) tons		0.376
Protein supplement cwt.		14.601
Annual Cash Expense		
Supplement 14.601 x 5.5		$ 80.31
Boar Service		4.50
Power and machinery		9.36
Equipment use		13.42
Hauling $.068 per cwt.		2.12
Veterinary, electricity, miscellaneous		12.48
Hay harvesting costs .031 x 4.04		1.25
		$123.44
Capital Coefficient 1st Year		
Breeding females		45.42
Equipment (½ cost of new equipment per unit)		39.89
		$208.76
Capital Coefficient 2nd Year		

Source: The coefficients were adjusted after consultation with Everett Stoneberg, Extension Service, Economics Department and Thomas Wickersham, Extension Service, Animal Husbandry Department, Iowa State University of Science and Technology. (22).

from livestock enterprises are born by the tenant. The latter receives as well all the benefits coming from these enterprises.[1]

1. Good to choice feeder calves fed on pasture

Good to choice calves are bought at weights of about 430 pounds. They are wintered on roughage and some grain and in the spring they are put to pasture for 130 days. They are fed to attain grade choice in the October market. Market weight averages 1052 pounds per head sold with a death loss of 2.5 percent of purchase weight.

2. Good to choice feeder calves fed in drylot

Good to choice feeder calves are purchased in October at weights about 430 pounds. They are wintered on roughage and some grain and put on full drylot feed in June. They are fed out to grade choice and marketed in September weighing an average of 103- pounds per head sold. Death loss is 2.5 percent of purchase weight.

3. Choice yearling steers

Choice yearling steers are purchased in October at weights of 621 pounds. After having been wintered on roughage and some grain, they are put on full drylot feed in early spring. Grade choice steers are marketed in June. Market weight is about 1121 pounds per head sold and death loss is estimated as 1 percent of purchase weight.

4. Medium yearling steers

Medium yearling steers are purchased at a weight of 670 pounds in November and are wintered on roughage and limited grain. They are put

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[1]This is not the case of livestock-share leases in which both costs and returns are shared between landlord and tenant.

on full feed in drylot at the end of winter and they are fed out to grade good. Market weight is about 1030 pounds per head sold and death loss is .5 percent of purchase weight,

5. <u>One-litter spring hogs (1:0 ratio)</u>

Pigs are farrowed in April and marketed in November at a weight of 240 pounds per head. Litters average 7.3 pigs weaned. Pork sold per litter including a 350 pound sow averages 1818 pounds. Total feed, capital, labor, livestock equipment, building space requirements and total returns are calculated on the unit basis of a sow and one litter.

6. <u>Two-litter spring and fall hogs (1:1 ratio)</u>

Pigs are farrowed in April and November and marketed in October and May at a weight of 230 pounds per head. The two litters average 14.6 pigs weaned. The amount of pork sold is 3120 pounds, not including a 300-pound sow. Different resource requirements are calculated on the unit basis of a sow and two litters.

V. LONG-TERM AND SHORT-TERM FARM PLANS: EMPIRICAL RESULTS

One of the objectives of this study was to obtain short-term and long-term optimal farm plans in order to observe the effect of time on resource allocation on a rented farm under different leasing arrangements and also on one operated by the owner.

This chapter presents in certain detail the empirical results of the different optimal plans and thus achieves this objective. The other objective of this study was to test some hypotheses about the nature of inter-temporal inefficiencies due *per se* to leasing systems. This aspect of the analysis will be taken up in the following chapter.

A. Optimal Long-Term Plans for a Crop-Share Rented Farm Under Customary Leasing Arrangements

The dynamic model used in obtaining these optimal plans is basically the one presented in Figure 5. The number of activities included in the empirical situation is considerably greater than that of the model. The input-output matrix is of order 54 X 455. A great part of the 455 activities is formed of crop rotation activities, which as explained in Chapter IV, can be at any three levels of conservation and fertilization.

In determining the optimum combination of enterprises, given the restrictions imposed by resources and the goals of the farmer, the tenant's objective row is first maximized at different levels of capital. Then at a specific level of capital, i.e., $8,250, the optimum farm plan for the landlord is obtained by maximizing his objective function subject to the same restrictions as in the case of the tenant.

1. Tenant's 6-year optimum plan

Table 32 gives a summary of the optimum 6-year plan for a tenant-operated 220-acre farm under customary crop-share lease in southwestern Iowa. The level of capital available to the firm amounts to \$8,250. Of this amount, \$3,460 over the 6-year period is contributed by the landlord and the rest by the tenant.[1] In the first year, i.e., year 0, the landlord contributes \$577 and the tenant \$6,750. The amount of capital resources used for family consumption is taken each year from the capital supply. That explains the relatively high level of capital; \$4,460 are required each year for family consumption and other fixed costs.

In the second year, the tenant's returns are reinvested in the firm. In this year, the tenant's capital is \$4,854, \$3,891 coming from the previous year's returns and the remainder from the initial contribution of \$1,050.[2] The amount of capital invested in the following years is given in detail in Table 32. It can be noted that capital supply does not increase smoothly over time. The reason can be attributed to the model which is set in such a way that it does not include a yearly hay selling activity but only in odd years. This explains the apparently erratic changes in capital supply and also in total returns.

The crop rotations at the levels given in Table 32 for the 6-year period on Land A and B are the crop combinations which maximize the total returns in year 5 subject to meeting the restraing of family living and

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[1]The tenant contributes \$6,750 in year 0, \$1,000 in year 1, \$1,102.50 in year 2 and \$572 in year 3. All this amounts to \$9,000 discounted to its present value in year 0.

[2]The discrepancy is due to rounding errors.

other fixed costs. It is interesting to observe the pattern of resource allocation in this dynamic framework. Figure 4 gives a graphic summary of the rotations included in the optimum plan for the tenant. As before, in any crop rotation the capital letters symbolize the different crops, the superscript the type of land and the subscripts the level of fertilization, the level of conservation and the year the rotation is started.

For instance, $CCOM^{A}_{2,1,0}$ is a 4-year corn-corn-oats-meadow rotation starting in year 0 at a high level of fertilization and at a low level of conservation (contouring). This rotation uses up almost the total 60 acres supply of Land A. The other two rotations included in year 0 use up the supply of Land B. $COM^{B}_{2,1,0}$ takes 15.2 acres and $COM^{B}_{2,2,0}$ takes 144.6 acres. These two enterprises are the same except for the fact that the first uses only contouring as a conservation practice whereas the second uses terraces.

It can be seen in Figure 7 that as capital increases over time the number of crop rotations using a high level of conservation also increases. For instance in year 4 practically all of Land B is terraced, $CCOM^{B}_{2,2,3}$ and $COM^{B}_{2,2,3}$ coming in at a high level of conservation. Even in Land A, $CCC^{A}_{w,w,4}$ comes into the plan at a high level of conservation. It sould be remembered that Land A has a slope of 1-5% which usually does not require terracing. These results show, however, that if soil depleting rotations such as continuous corn are grown, terracing becomes profitable in that type of land when there is ample capital available.

The livestock enterprises included in the tenant's optimum plan consist each year of 2-litter hogs. These are capital intensive enterprises

Table 32. Optimum tenant 6-year plan for a 220-acre farm under a customary crop-share leasing arrangement in centr

Year of plan	Discounted operating capital[a]	Crop rotation: Type of land	Crop rotation: Rotation	Crop rotation: Acres	Livestock: Type	Livestock: Number of units	Other activities: Type	Other activities: Num of u
0	Landlord: $577	A	$CCOM^A_{2,1,0}$	59.9	Hogs 2 - litter	3.6	Hay transfer	190.
		B	$COM^B_{2,1,0}$	15.2			Family living	$4,4
	Tenant: $6,759	B	$COM^B_{2,2,0}$	144.6				
1	Landlord: $605	A	$CCOM^A_{2,1,0}$	59.9	Hogs 2 - litter	8.4	Hay selling	352.
		B	$COM^B_{2,1,0}$	15.2			Corn selling	1761
	Tenant: $4,854	B	$COM^B_{2,2,0}$	144.6			Family living	$4,4
		A	$CCOM^A_{2,1,1}$	.1				
2	Landlord: $636	A	$CCOM^A_{2,1,0}$	59.9	Hogs 2 - litter	9.6	Hay transfer	190
		B	$COM^B_{2,1,0}$	15.2			Corn selling	1693
	Tenant: $6,605	B	$COM^B_{2,2,0}$	144.6			Family living	$4,4
		A	$CCOM^A_{2,1,1}$	.1				
3	Landlord: $668	A	$CCOM^A_{2,1,0}$	59.9	Hogs 2 - litter	15.4	Hay selling	377.
		A	$CCOM^A_{2,1,1}$	.1			Corn selling	304.
	Tenant: $5,317	B	$COM^B_{2,2,3}$	15.3			Family living	$4,4
		B	$COM^{2B}_{2,2,3}$	144.6				
4	Landlord: $701	A	$CCOM^A_{2,1,1}$	.1	Hogs 2 - litter	17.8	Hay transfer	183
		B	$COM^B_{2,2,3}$	15.3			Corn buying	73.6
	Tenant: $6,916	B	$COM^{2B}_{2,2,3}$	144.6			Family living	$4,4
		A	$CCOM^A_{2,1,4}$	54.4				
		A	$CCC^A_{2,2,4}$	5.6				

[a]Includes also capital for family living consumption. Capital is discounted to year 0. Landlord's capital, he

[b]Present value of total returns of the terminal year is maximized. Returns are discounted to year 0.

...farm under a customary crop-share leasing arrangement in southwestern Iowa with a total operating capital of $8,250

	Optimum Combination of Enterprises					
	Livestock		Other activities			
...es	Type	Number of units	Type	Number of units	Limiting resources	Discounted total returns[b]
.9	Hogs 2 - litter	3.8	Hay transfer	190.9 tons	Capital landlord	Landlord:
.2			Family living	$4,460	Capital tenant	$1,372
.6					Corn	Tenant:
					Land B	$3,691
.9	Hogs 2 - litter	8.4	Hay selling	352.5 tons	Capital landlord	Landlord:
.2			Corn selling	1761.2 bu.	Capital tenant	$4,222
.6			Family living	$4,460	Land A	Tenant:
.1					Land B	$5,635
.9	Hogs 2 - litter	9.6	Hay transfer	190 tons	Capital landlord	Landlord:
.2			Corn selling	1493.9 bu.	Capital tenant	$4,029
.6			Family living	$4,460	Land A	Tenant:
.1					Land B	$4,815
.9	Hogs 2 - litter	15.4	Hay selling	377.9 tons	Capital landlord	Landlord:
.1			Corn selling	304.7 bu.	Capital tenant	$3,659
.3			Family living	$4,460	Land A	Tenant:
.6					Land B	$6,691
.1	Hogs 2 - litter	17.8	Hay transfer	183 tons	Capital landlord	Landlord:
.3			Corn buying	73.6 bu.	Capital tenant	$3,668
.6			Family living	$4,460	Land A	Tenant:
.4					Corn	$7,370
.6						

...ption. Capital is discounted to year 0. Landlord's capital, however, is not discounted to year 0.

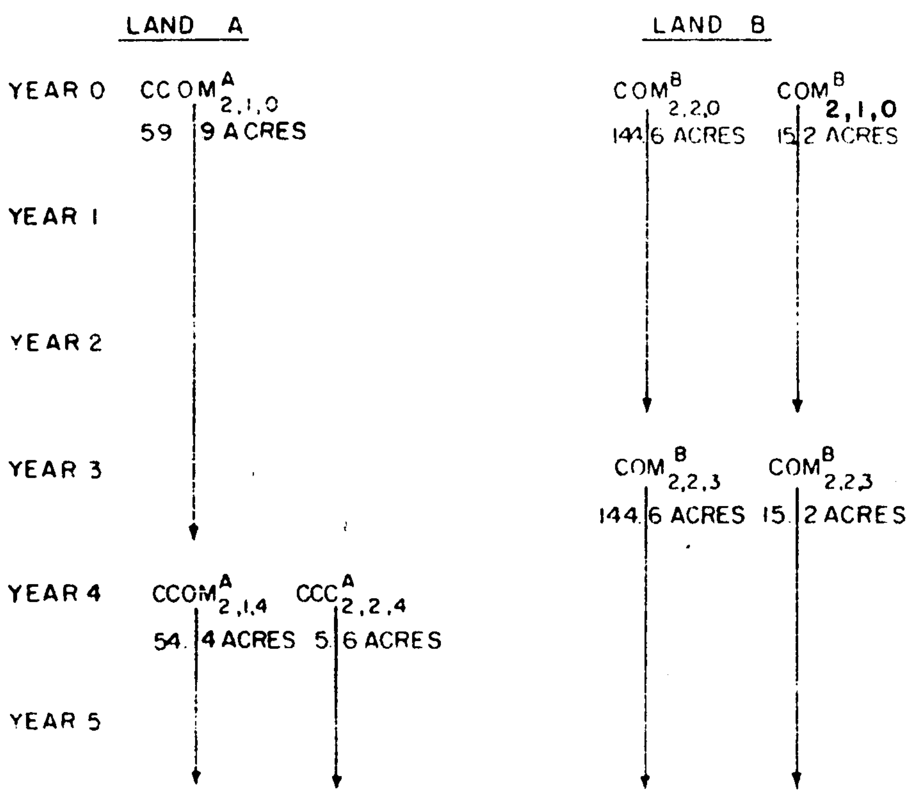
...year is maximized. Returns are discounted to year 0.

Table 32 (Continued).

		Optimum Combination of Enterprises						
		Crop rotation			Livestock		Other activities	
Year of plan	Discounted operating capital[a]	Type of land	Rotation	Acres	Type	Number of units	Type	Number of units
5	Landlord: $736	D	$CCM^{D}_{2,2,3}$	19.3	Hogs 2 - litter	20.0	Hay selling	116.7
		B	$CCM^{B}_{2,2,3}$	144.6	Choice yearling steers	7.9	Corn buying	976.3
	Tenant: $7,333	A	$CCOM^{A}_{2,1,4}$	54.4			Family living	$4,460
		A	$CCCA_{2,2,4}$	5.6				

	Optimum Combination of Enterprises					Limiting resources	Discounted total returns[b]
	Livestock		Other activities				
Acres	Type	Number of units	Type	Number of units			
15.3	Hogs 2 - litter	20.0	Hay selling	116.7 tons		Capital landlord	Landlord:
	Choice yearling		Corn buying	976.3 bu.		Capital tenant	$5,908
144.6	steers	7.9	Family living	$4,460		Land A	
						Corn	Tenant:
54.4						Livestock space	$12,275
5.6							

Figure 7. Optimal combination of crop rotations in the tenant's six-year plan


LAND A
LAND B
YEAR 0
YEAR 1
YEAR 2
YEAR 3
YEAR 4
YEAR 5
$CCOM^{A}_{2,1,0}$
59.9 ACRES
$COM^{B}_{2,2,0}$
144.6 ACRES
$COM^{B}_{2,1,0}$
15.2 ACRES
$COM^{B}_{2,2,3}$
144.6 ACRES
$COM^{B}_{2,2,3}$
15.2 ACRES
$CCOM^{A}_{2,1,4}$
54.4 ACRES
$CCC^{A}_{2,2,4}$
5.6 ACRES

and only in the last year is the livestock building space capacity of the farm exhausted. In the year 5, a new livestock enterprise, choice yearling steers, comes into the plan. This enterprise does not require any building space and the only resources which can limit it are capital, labor and forage.

Among other activities which appear each year in the tenant's plan is family living which includes the yearly family consumption and certain added fixed costs.[1] A corn selling activity appears in years 1, 2 and 3. In year 0, no corn is sold because all is fed to livestock. In years 4 and 5, additional corn is bought because corn becomes the limiting resource for livestock activities.

Hay transfer is an activity selected in years 0, 2 and 4 of the optimum plan. Only in years 1, 3, and 5 is hay selling present. The non-inclusion of a hay selling activity in the even years could be justified by the fact that the hay market is rather imperfect in many rural localities.

The last column of Table 32 gives the yearly discounted returns for both landlord and tenant. It can be noticed that these increase through time although not in a monotonic way. The reason as expressed above is that the inclusion of a hay selling activity only in odd years produces, like in years 2 and 3, the jerks in the growth of total returns. Besides, since returns are discounted to the present value in year 0, it happens that an increase in returns in money terms for a specific year may appear

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[1]The detail is given in Table 4.

like a decrease in money terms of year 0. This is more true, the higher is the discount rate.[1]

The relatively higher level of profit of the last year can be explained by the fact that in that year discounted total returns include not only the returns of crops produced and sold within that year but also the discounted returns of crops sold at the beginning of the following year.

2. Landlord's optimum 6-year plan

A summary of a landlord's optimum plan for the same farm situation examined in the previous paragraph is presented in Table 33. It can be noticed that the operating capital is the same in this plan, the landlord's optimum plan, and the above tenant's plan. That is, the total operating capital available to the firm is $8,250 not including the amount available for family consumption in the first year. In that same year, the landlord contributes $577 and the tenant $6,750, the same level of capital as in the tenant's optimum plan. This permits comparison of the two plans.

The choice of rotations is illustrated in Figure 8. The pattern differs somewhat from the tenant's optimum plan. First, the rotations included in the landlord's plan are generally the same except that CCC, continuous corn, comes into the plan much earlier (year 1). In the tenant's optimum plan, continuous corn appears only in the last two years and in a limited extension.

Second, in the first year 10.8 acres of Land A are left in disposal,

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[1]In this study a 5% rate of interest was used.

Table 33. Optimum landlord 6-year plan for a 220-acre farm under a customary crop-share leasing arrangement in southern

Year of plan	Operating capital[a]	Crop rotation: Type of land	Crop rotation: Rotation	Crop rotation: Acres	Livestock: Type	Livestock: Number of units	Other activities: Type	Other activities: Number of units
0	Landlord: $577	B	$CCM^B_{2,1,0}$	159.8	Hogs 2 - litters	4.0	Hay transfer	178.1 t
		A	$CCOM^A_{2,1,0}$	49.1			Family living	$4,460
	Tenant: $6,759	A	$CsbCOM^A_{2,1,0}$	.1			Corn buying	118.21
							Land A disposal	10.8 ac
1	Landlord: $605	B	$CCM^B_{2,1,0}$	159.8	Hogs 2 - litters	7.4	Hay selling	356.9 t
		A	$CCOM^A_{2,1,0}$	49.1			Corn selling	1,991.9
	Tenant: $4,771	A	$CsbCOM^A_{2,1,0}$	.1			Family living	$4,460
		B	$CCM^B_{2,1,1}$	.2				
		A	$CCCCO^A_{2,2,1}$	10.8				
2	Landlord: $636	B	$CCM^B_{2,1,0}$	159.8	Hogs 2 - litters	6.5	Hay transfer	178.1 t
		A	$CCOM^A_{2,1,0}$	49.1			Corn selling	1,742.1
	Tenant: $6,489	A	$CsbCOM^A_{2,1,0}$	.1			Family living	$4,460
		B	$CCM^B_{2,1,1}$	.2				
		A	$CCCCO^A_{2,2,1}$	10.8				
3		A	$CCOM^A_{2,1,0}$	49.1	Hogs 2 - litters	13.4	Hay selling	355.8 t
	Landlord: $668	A	$CsbCOM^A_{2,1,0}$	.1			Corn selling	753.7 bu
		B	$CCM^B_{2,1,1}$	.2			Family living	$4,460
	Tenant: $5,290	A	$CCCCO^A_{2,2,1}$	10.8				
		B	$CCCOM^B_{2,2,3}$	9.8				
		B	$CCM^B_{2,2,3}$	150.0				

re farm under a customary crop-share leasing arrangement in southwestern Iowa with a total operating capital of $5,890

Optimum Combination of Enterprises

	Livestock		Other activities			
es	Type	Number of units	Type	Number of units	Limiting resources	Discounted total returns b
.8	Hogs 2 - litters	4.0	Hay transfer	178.1 tons	Capital landlord	Landlord:
			Family living	$4,460	Capital tenant	$1,829
.1			Corn buying	118.21 bu.	Corn	
			Land A disposal	10.8 acres	Land B	Tenant:
.1						$3,750
.8	Hogs 2 - litters	7.4	Hay selling	356.9 tons	Capital landlord	Landlord:
			Corn selling	1,991.9 bu.	Capital tenant	$3,645
.1			Family living	$4,460	Land A	
					Land B	Tenant:
.1						$5,452
.2						
.8						
.8	Hogs 2 - litters	8.5	Hay transfer	178.1 tons	Capital landlord	Landlord:
			Corn selling	1,742.1 bu.	Capital tenant	$4,052
.1			Family living	$4,460	Land A	
					Land B	Tenant:
.1						$4,786
.2						
.8						
.1	Hogs 2 - litters	13.4	Hay selling	355.8 tons	Capital landlord	
			Corn selling	753.7 bu.	Capital tenant	Landlord:
.1			Family living	$4,460	Land A	$3,876
					Land B	
2						Tenant:
8						$5,380
8						
0						

Table 33 (Continued).

Year of plan	Operating capital[a]	Optimum Combination of Enterprises						
		Crop rotation			Livestock		Other activities	
		Type of land	Rotation	Acres	Type	Number of units	Type	Number of units
4	Landlord $701	A	$CoOCM^A_{2,1,0}$	.1	Hogs 2 - litters	13.6	Hay transfer	141.9
	Tenant: $6,360	A	$CCOCM^A_{2,2,1}$	10.6			Corn selling	663.6
		B	$CCOM^B_{2,2,3}$	9.6			Family living	$4,46[illegible]
		B	$CCM^B_{2,2,3}$	150.0				
		B	$CCOM^B_{2,1,4}$	.2				
		A	$CCC^A_{2,2,4}$	49.1				
5	Landlord: $736	A	$CCOCM^A_{2,2,1}$	10.6	Hogs 2 - litters	20.0	Hay selling	251.0
	Tenant: $6,034	B	$CCOM^B_{2,2,3}$	9.6			Corn selling	179.3
		B	$CCM^B_{2,2,3}$	190.0			Family living	$4,46[illegible]
		B	$CCOM^B_{2,1,4}$	.2				
		A	$CCC^A_{2,2,4}$	49.1				

[a]Includes also capital for family living consumption. Capital is discounted to year 0. Landlord's capital

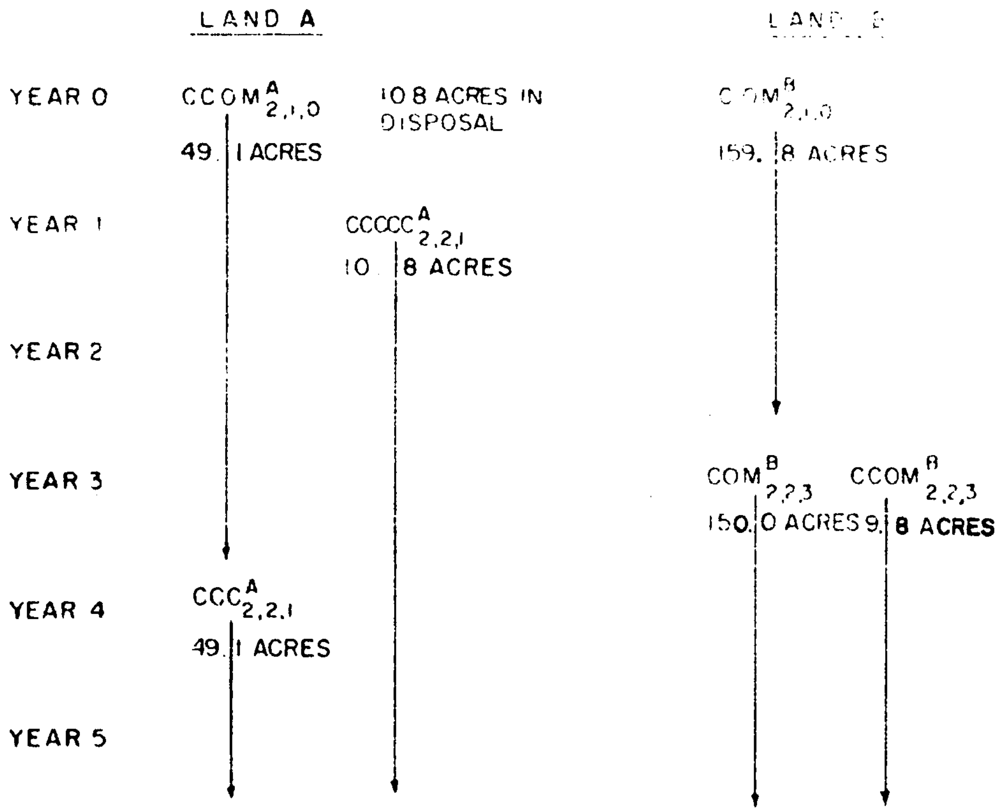
[b]Present value of total returns of the terminal year is maximized. Returns are discounted to year 0.

	Optimum Combination of Enterprises					
	Livestock		Other activities			
Acres	Type	Number of units	Type	Number of units	Limiting resources	Discounted total returns[b]
.1	Hogs 2 - litters	13.6	Hay transfer	141.5 tons	Capital tenant	
			Corn selling	668.8 bu.	Capital landlord	Landlord:
10.6			Family living	$4,460	Land A	$3,745
					Land B	
9.8						Tenant:
150.0						$6,050
.2						
49.1						
10.6	Hogs 2 - litters	20.0	Hay selling	251.0 tons	Capital tenant	
			Corn selling	179.3 bu.	Capital landlord	Landlord:
9.8			Family living	$4,460	Land A	$5,770
					Land B	
150.0					Livestock space	Tenant:
						$11,438
.2						
49.1						

ing consumption. Capital is discounted to year 0. Landlord's capital, however, is not discounted to year 0.

terminal year is maximized. Returns are discounted to year 0.

Figure 8. Optimal combination of crop rotations in the landlord's six-year plan


LAND A
YEAR 0
YEAR 1
YEAR 2
YEAR 3
YEAR 4
YEAR 5
CCOM $^{A}_{2,1,0}$
49.1 ACRES
10 8 ACRES IN DISPOSAL
CCCCC $^{A}_{2,2,1}$
10.8 ACRES
CCC $^{A}_{2,2,1}$
49.1 ACRES
COM $^{B}_{2,1,0}$
159.8 ACRES
COM $^{B}_{2,2,3}$
150.0 ACRES
CCOM $^{B}_{2,2,3}$
9.8 ACRES

i.e., left in permanent pasture or rented out. In this respect it is important to point out that our model does not admit continuous corn for more than five successive years. A 5-year continuous corn rotation can be started only in the second year.

Thirdly, in the last two years all of Land A and B is terraced, whereas in the tenant's optimum plan approximately 55 acres of rotation Land A used contouring but not terracing.

The livestock enterprises are reduced to 2-litter hogs only. It can be noticed that in this plan comparatively less resources are diverted to livestock than in the tenant's plan.

The other activities included in the landlord's plan are the same as in the tenant's except for corn selling which replaces corn buying in the last two years. The reason is that the crops selected have a higher proportion of corn than in the tenant's plan. Besides, the level of livestock activities is lower in this plan than in the tenant's and therefore less corn is fed to the cattle.

The last year returns are higher for the landlord relative to the tenant's plan (Figure 9). Here, total returns for the landlord are $6,770 against $5,908 and for the tenant $11,438 against $12,275 in the tenant's optimum plan. Total returns for the firm are approximately the same for the two plans: $18,208 in the landlord's optimum plan against $18,183 in the tenant's optimum plan.

Figure 6 gives an idea of the level of discounted returns of alternative plans in every year of the 6-year plan.

It can be observed here that the difference in returns between the landlord's and the tenant's optimal plans can be attributed to intra-temporal inefficiencies due per se to leasing systems. In effect, customary crop-share leases violate incentive conditions one and two, fact which accounts for the difference in returns between the two optimal plans. Since we are not specifically interested in this type of inefficiencies but rather in inter-temporal ones, we will not give more time to this subject.

However, it can be mentioned here that if intra-temporal inefficiencies were to be measured, the returns from these plans and those from similar plans under a "perfect lease" should be compared. The difference in discounted returns between the two set of plans could be then attributed to intra-temporal inefficiencies caused per se by leasing arrangements.

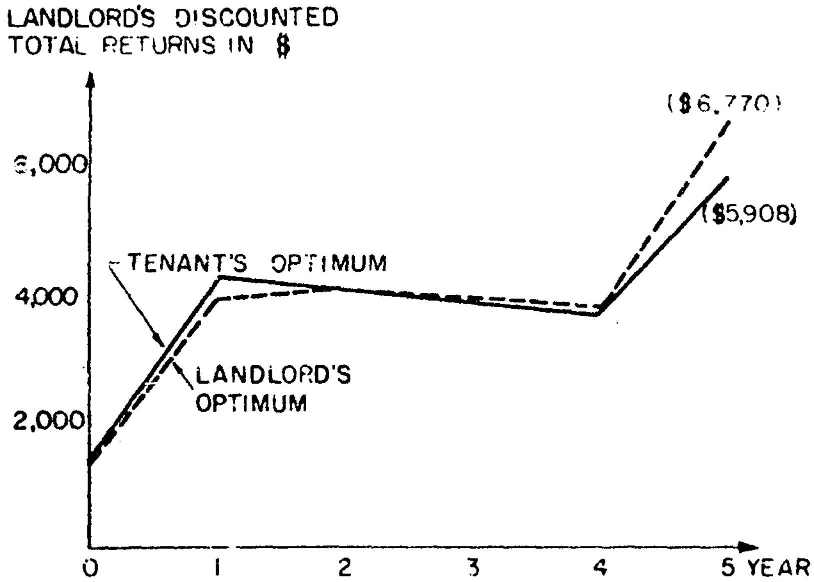
B. An Optimum Long-Term Plan for an Owner-Operated Farm

Table 34 gives a summary of the optimum 6-year plan for an owner-operated 220-acre farm in southwestern Iowa. This program which follows the model presented in Chapter III was run under the same restrictions as those for the tenant-operated farm. The only difference is that the operating capital available is higher than in the other two plans.[1]

The crop rotations included in this plan are only two: corn-corn-oats-meadow for Land B ($CCOM^B_{2,2,0}$ and $CCOM^B_{2,2,4}$) and continuous corn for Land A ($CCCCC^A_{2,2,1}$). It can be seen that these two rotations are used at a high

[1]The reader is referred to Chapter II in which the difficulties of comparing a dynamic owner-operator's optimum plan and a tenant's optimum plan are discussed.

Figure 9. Landlord's and tenant's discounted total returns in the six-year tenant's and landlord's optimal plan


LANDLORD'S DISCOUNTED TOTAL RETURNS IN $
($6,770)
6,000
($5,908)
TENANT'S OPTIMUM
4,000
LANDLORD'S OPTIMUM
2,000
0
1
2
3
4
5 YEAR

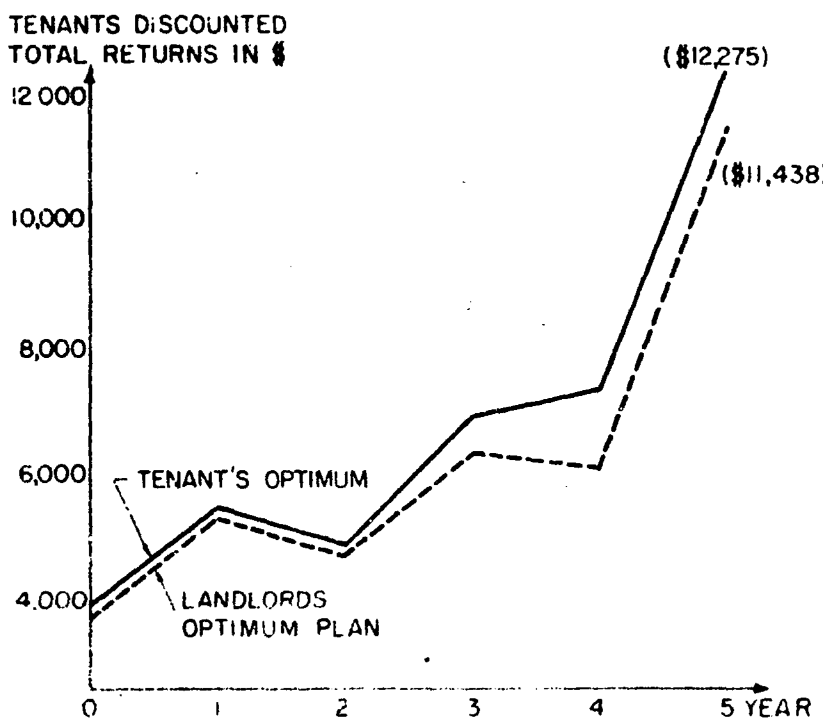

TENANTS DISCOUNTED TOTAL RETURNS IN $
($12,275)
12 000
($11,438)
10,000
8,000
6,000
TENANT'S OPTIMUM
4,000
LANDLORDS OPTIMUM PLAN
0
1
2
3
4
5 YEAR

Table 34. Optimum owner-operator 6-year plan for a 220-acre farm in southwestern Iowa with a high level of operating capit

		Optimum Combination of Enterprises						
		Crop rotation			Livestock		Other activities	
Year of plan	Operating capital[a]	Type of land	Rotation	Acres	Type	Number of units	Type	Number of units
0	$12,900[b]	B	$CCOM^{B}_{2,2,0}$	160	Hogs 2 - litter	15.3	Hay transfer Corn buying Family living Land A disposal	105.6 tons 2259.2 bu. $4,460 60 acres
1	$9,352	A B	$CCCCO^{A}_{2,2,1}$ $CCOM^{B}_{2,2,0}$	60 160	Hogs 2 - litter	20	Hay selling Corn selling Capital selling Family living	210 tons 1428.6 bu. $849 $4,460
2	$26,253	A B	$CCCCO^{A}_{2,2,1}$ $CCOM^{B}_{2,2,0}$	60 160	Hogs 2 - litter	20	Hay transfer Corn selling Capital selling Family living	103 tons 5473 bu. $7,221 $4,460
3	$18,100	A B	$CCCCO^{A}_{2,2,1}$ $CCOM^{B}_{2,2,0}$	60 160	Hogs 2 - litter Medium yearling steers	20 12.5	Hay selling Corn selling Capital selling Family living	169 tons 4763 bu. $11,470 $4,460
4	$22,749	A B	$CCCCO^{A}_{2,2,1}$ $CCOM^{B}_{2,2,4}$	60 160	Hogs 2 - litter Medium yearling steers	20 20	Hay transfer Corn selling Capital selling Family living	63 tons 4770 bu. $14,375 $4,460
5	$78,015	A B	$CCCCO^{A}_{2,2,1}$ $CCOM^{B}_{2,2,4}$	60 160	Hogs 2 - litter Medium yearling steers	20 20	Hay selling Corn selling Capital selling Family living	128 tons 4733 bu. $22,918 $4,460

[a]Discounted to year 0.

[b]It includes allowance for family consumption.

...-acre farm in southwestern Iowa with a high level of operating capital

Optimum Combination of Enterprises					
Livestock		Other activities			
Type	Number of units	Type	Number of units	Limiting resources	Discounted total returns[a]
Hogs 2 - litter	15.3	Hay transfer	105.6 tons	Capital	$9,458
		Corn buying	2269.2 bu.	Land B	
		Family living	$4,460	Corn	
		Land A disposal	60 acres		
Hogs 2 - litter	20	Hay selling	210 tons	Land A	
		Corn selling	1428.6 bu.	Land B	
		Capital selling	$849	Livestock space	$15,980
		Family living	$4,460		
Hogs 2 - litter	20	Hay transfer	103 tons	Land A	
		Corn selling	5473 bu.	Land B	$19,587
		Capital selling	$7,221	Livestock space	
		Family living	$4,460		
Hogs 2 - litter	20	Hay selling	169 tons	Land A	
Medium yearling		Corn selling	4763 bu.	Land B	$23,613
steers	12.5	Capital selling	$11,470	Livestock space	
		Family living	$4,460		
Hogs 2 - litter	20	Hay transfer	63 tons	Land A	
Medium yearling		Corn selling	4770 bu.	Land B	$27,986
steers	20	Capital selling	$14,375	Livestock space	
		Family living	$4,460	Labor	
Hogs 2 - litter	20	Hay selling	128 tons	Land A	
Medium yearling		Corn selling	4733 bu.	Land B	$36,668
steers	20	Capital selling	$22,918	Livestock space	
		Family living	$4,460	Labor	

level of fertilization and conservation (terracing).

Continuous corn comes into the optimum plan only in the second year. In year 0 all Land A is in disposal. This means that it is more profitable for the tenant to allocate his capital to livestock enterprises in the first year, rather than to crop enterprises other than continuous corn.[1]

Hog activities appear at a high level since the first year. In the second year, the livestock building space is exhausted and excess of capital is invested outside of the farm. This is indicated by the inclusion of a capital selling activity in year 1. According to Table 34, $549 are invested outside the farm in this year.

In year 3, a new livestock enterprise comes into the plan: medium yearling steers.[2] This activity does not consume any building space.

In year 4, it attains a level of 20 units which is not surpassed the next year. The reason is that then the labor resources become limiting. Hence, the investment for the excess capital in the last two years is exclusively channelled through the capital selling activity which attains the level of $22,518 in the last year.

Discounted total returns increase consistently from $9,458 in the first year to $36,668 in the last year.

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[1]The model does not permit continuous corn starting in year 0.

[2]The model does not permit this activity to come into the plan before year 3.

C. Three Consecutive Two-Year Optima Plans for a Tenant-Operated Farm

One of the objectives of this study was to program three consecutive optima plans for the same tenant-operated farm in Southwestern Iowa used in the long-term optima plans presented above. The crop restrictions imposed by share leasing arrangements are identical to those of the long-term plans. Thus, it will become possible to compare the tenant's long-term optimum plan with the consecutive short-term plans in order to detect inter-temporal inefficiencies in resource allocation. In the first situation the tenant has a supposedly adequate planing horizon whereas in the second one he has a planning horizon limited to two years.

All the programs presented below follow the dynamic programming model presented in Figure 6 of Chapter III. It should be recalled that this model has single crops instead of rotations as activities and that no second-year activities start at a high level of conservation, i.e., with terracing. This is a reasonable assumption since a tenant with an expected two-year term on the farm would hardly plan to invest in terraces. He would not profit from the latter but rather would his successor on the farm. This is a common dissociation of benefits and costs.

1. First and second year optimum plan for a tenant-operated farm

Table 35 gives the optimum combination of enterprises for the first

Table 35. Optimum tenant 1st and 2nd year plan for a 220-acre farm under a customary crop-share leasing arrangement in

		Optimum Combination of Enterprises						
		Crop rotation			Livestock		Other activities	
Year of plan	Operating capital[a]	Type of land	Rotation	Acres	Type	Number of units	Type	Number of units
0	Landlord: $577	A	$\text{Corn}^{A}_{2,1,0}$	60.0	Hogs 2 - litters	.1	Family living	$4,460
		B	$\text{Corn}^{B}_{1,1,0}$	68.7			Corn buying[c]	14.7 bu.
	Tenant: $6,750	B	$\text{Corn}^{B}_{1,2,0}$	90.9			Corn disposal[b]	4,769 bu
		B	$\text{Oats}^{B}_{2,1,0}$	.4			Capital transfer[b]	$63.5
1	Landlord: $577	A	$\text{Soybeans}^{A}_{2,1,0}$	60.0	Hogs 2 - litters	2.5	Corn selling	194.2 bu
		B	$\text{Soybeans}^{B}_{1,1,0}$	35.7			Family living	$4,460
	Tenant: $6,057	B	$\text{Soybeans}^{B}_{1,2,0}$	90.9			Corn disposal landlord	800 bu.
		B	$\text{Oats}^{B}_{2,1,0}$	30.0				
		B	$\text{Meadow}^{B}_{2,1,0}$	.4				

[a]Discounted to year 0. Landlord's contribution is $577 per year and tenant's is $6,750 in year 0 and $1,000 in ye

[b]The discounted value of the landlord's corn in disposal is included in this figure.

…acre farm under a customary crop-share leasing arrangement in southwestern Iowa

Optimum Combination of Enterprises					
Livestock		Other activities			
Type	Number of units	Type	Number of units	Limiting resources	Discounted total returns
Hogs 2 - litters	.1	Family living	$4,460	Capital tenant	Landlord: $5,181[b]
		Corn buying[a]	14.7 bu.	Land A	
		Corn disposal[c]	4,769 bu.	Land B	Tenant: $5,058
		Capital transfer[c]	$63.5	Corn	
Hogs 2 - litters	2.5	Corn selling	194.2 bu.	Capital tenant	Landlord: $4,965[b]
		Family living	$4,460	Capital landlord	
		Corn disposal landlord	800 bu.	Land A	Tenant: $6,604
				Land B	

…577 per year and tenant's is $6,750 in year 0 and $1,000 in year 1.

…osal is included in this figure.

of three consecutive two-year tenant's plans. The crop enterprises selected by the tenant in year 0 consist almost exclusively of corn. The entire 60 acres of Land A are planted with corn at a high level of fertilization but at a low level of conservation (contouring).

Most of Land B is also allocated to corn enterprises. There are 68.7 acres of $C^B_{1,1,0}$ and 90.9 acres of $C^B_{1,2,0}$. The first activity uses a low level of fertilization and conservation. The second activity is also at a low level of fertilization but requires terraced land. Other activity appearing in this plan in a reduced scale is $0^B_{2,1,0}$ used as a nurse crop for meadow.

Capital is one of the restricting resources for the tenant in year 0. It is interesting to note that the tenant allocates his capital to crops in such a way that Land A, physically more productive, receives more fertilizer whereas Land B, which is more subject to soil erosion, gets more conservation practices.

In year 1 all of Land A is planted with soybeans. This does not also happen with Land B because some of it, that is 30 acres, is allocated to pasture.

Among the livestock activities there is only one which recurs in all plans. This is two-litter hogs which come in at a low level in this plan. This activity consumes a high amount of capital and therefore competes for it with the crop activities.

Other activities present in the plan are family living, forced into the plan at the same level as in all other plans, and tenant corn buying which is used to feed the livestock.[1]

The discounted gross returns of the tenant in year 1 are $6,004 and the landlord's $4,968. The latter include the discounted value of the landlord's corn disposal.

2. First and second year optimum plan for a rented farm maximizing the landlord's objective row.

Table 36 presents the optimum combination of enterprises for the same two-year program explained in the last section but with the difference that here the landlord's objective row is maximized instead of the tenant's. The purpose of this program is to point out in passing the existence of intra-temporal dissociations in leasing systems.

The crop activities selected in this plan do not differ much from the ones in the previous optimum plan. In year 0 there is a sizable amount of land planted with corn. In year 1 the landlord optimizing returns of the second year substitutes corn for soybeans. In effect, all of Land A is given to corn and part of Land B, that is, 60 acres also grow corn.

A difference that should be noted is that in the landlord's optimum plan oats uses only a low level of fertilizer whereas in the tenant's optimum plan oats uses a high level of fertilization. The reason is that oats under customary sharing arrangements are split between landlord and tenant in a 40-60 basis. This evidently produces intra-temporal dissociations of benefits and costs.

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[1]No corn is produced to be fed in the first year since according to the model only oats, i.e., corn equivalent, can be produced and fed to the cattle in the same year.

A further difference between this plan presented in Table 36 and the tenant's in Table 35 is that here no livestock activities come into the optimum plan. The landlord who has no interest in those activities prefers the tenant to allocate his capital resources to crop activities.

The level of total returns attained by the landlord in the second year is $5,164. In the tenant's optimum plan these returns were $4,968. There is a difference in favor of the landlord of $196 detween the landlord's discounted returns in the two optima plans. The discounted returns for the firm are higher, however, in the tenant's optimum plan. In effect, there are $774 more of total returns for landlord and tenant in the plan of Table 35 than in the landlord's plan. The reason is that the first plan includes livestock activities which have a larger return to invested capital.

3. <u>Third and fourth year optimum plan for a tenant-operated farm</u>

Table 38 summarizes the optimum plan for the same farm as in the previous problems. The tenant's objective funcgion is maximized here. These programs are a continuation of the tenant's first and second year as presented in Table 35. The tenant's capital supply in year 2 includes the total returns obtained in year 1. They amount to $6,004. Besides the tenant contributes $1,000 in year 2 and $500 in year 3.[1] The land restrictions of this program also depend on the crop activities selected in years 0 and 1.

In year 2 all Land A is dedicated to corn at a high level of fer-

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[1]These are exactly the same amounts contributed by the tenant in the 6-year plan presented in the first section of this chapter.

Table 36. Optimum landlord 1st and 2nd year plan for a 220-acre farm under a customary crop-share leasing arrangement i

operating capital

Year of plan	Operating capital[a]	Optimum Combination of Enterprises: Crops: Type of land	Crop	Acre	Livestock: Type	Number of units	Other Activities: Type	Number of units
0	Landlord:	A	$Corn^{A}_{1,1,0}$	50.8	-		Family living	$4460
	$577	A	$Corn^{A}_{2,2,0}$	9.2			Capital transfer[b]	$10478
		B	$Corn^{B}_{1,1,0}$	90.5			Corn selling landlord	5045 bu
	Tenant:	B	$Corn^{B}_{1,2,0}$	43.8			Corn selling tenant	5045 bu
	$6750	B	$Corn^{B}_{2,2,0}$	25.3				
		B	$Meadow_{2,0}$	.4				
1	Landlord:	A	$Corn^{A}_{2,1,1}$	50.8	-		Family living	$4460
	$577	A	$Corn^{A}_{2,2,1}$	9.2			Corn selling tenant	259bu
		B	$Corn^{B}_{2,1,1}$	60.5			Corn selling landlord	173 bu
		B	$Oats^{B}_{1,1,1}$	30.0				
	Tenant:	B	$Soybeans^{B}_{1,2,1}$	43.8				
	$6465	B	$Soybeans^{B}_{2,2,1}$	25.3				
		B	$Meadow^{B}_{2,0,1}$	.4				

[a] Discounted to year 0. Landlord's contribution is $577 per year and tenant's is $6750 in year 0 and $1000 in year

[b] Discounted to present value in year 0.

for a 220-acre farm under a customary crop-share leasing arrangement in southwestern Iowa with $8,250 of

	Optimum Combination of Enterprises					
	Livestock		Other Activities			
	Type	Number of units	Type	Number of units	Limiting resources	Total returns[b]
0.8	o		Family living	$4460	Capital tenant	Landlord:
9.2			Capital transfer[1]	$10478	Land A	$5283
0.5			Corn selling landlord	5045 bu	Land B	
3.8			Corn selling tenant	5045 bu		Tenant:
5.3						$5478
.4						
0.8	o		Family living	$4460	Capital Landlord	
9.2			Corn selling tenant	259bu	Capital Tenant	Landlord:
0.5			Corn selling landlord	173 bu	Land A	$5164
0.0					Land B	
1 43.8						Tenant:
1 85.3						$5034
.4						

ion is $577 per year and tenant's is $6750 in year 0 and $1000 in year 1.

tilization. Land B has also 130 acres of corn all at a high level of conservation. The new crop which comes into this plan is meadow which uses 40 acres of Land B.

In year 3 all the land is under cultivation using a high amount of fertilizer. Capital is evidently more abundant in this third year. All of Land B is terraced except 40 acres. Land A is not terraced but contouring is used to grow corn and soybeans.

Two-litter hogs come into the plan at a slightly higher level. Other activities are tenant's hay selling in year 2 and tenant's corn selling in year 3. The landlord's share of corn remains in disposal because the program does not maximize his total returns of year 3 but rather the tenant's. The value of the landlord's corn disposal is credited however, to his total returns.

The discounted total returns of the tenant in year 3 are $5,838. In year 1 they were $6,004. The landlord's discounted total returns are $3,630, considerably lower than in year 1 when they amounted to $4,968.

4. <u>Fifth and sixth year optimum plan for a tenant-operated farm</u>

The optimum combination of enterprises for a tenant-operated farm is presented in table 38. This plan is also a continuation of the tenant's third and fourth year plan. That is the operating capital contributed by the tenant is nothing but the total returns earned in year 3. Likewise yields of both Land A and B are a function of the crops grown in the four previous years.

A brief look at the crop activities selected in this plan indicates that in the last two years there is an increase of oats and meadow. In year 4 there are 37.3 acres of oats and 82.6 of meadow. In year 5 there

Table 37. Optimum tenant 3rd and 4th year plan for a 220-acre farm under a customary crop-share leasing ar

Year of plan	Operating capital[a]	Optimum Combination of Enterprises					
		Crop activities			Livestock activities		Other acti
		Type of land	Crop	Acres	Type	Number of units	Type
2	Landlord: $577	A	$C^A_{2,1,1}$	60	Hogs 2 - litters	1.6	Family living
		B	$C^B_{1,2,2}$	98.5			Corn Buying[c]
		B	$C^B_{2,2,2}$	21.4			Corn Disposal[d]
	Tenant:	B	$M^B_{2,0,2}$	39.6			Capital Transf
	$7004	B	$M^B_{2,1,2}$	.4			Hay Selling[f]
3	Landlord:	A	$C^A_{2,1,2}$	9.3	Hogs 2 - litters	3.3	Family living
	$577	A	$Sb^A_{2,1,2}$	50.7			Corn Selling[c]
		B	$C^B_{2,0,2}$	39.6			Corn Disposal[b]
	Tenant:	B	$C^B_{2,2,2}$	37.2			
	$4943	B	$C^B_{2,2,2}$	82.8			
		B	$M^B_{2,1,2}$	.4			

[a] Discounted to year 0. Landlord's contribution is $577 per year and tenant's is $1000 in year 2 a year 1 of the tenant's optimum plan shown in table 35 are reinvested in the farm in year 2. The

[b] The discounted value of the landlord's corn in disposal is included in this amount.

ion for a 220-acre farm under a customary crop-share leasing arrangement in southwestern Iowa.

	Optimum Combination of Enterprises					
ies	Livestock activities		Other activities			
Acres	Type	Number of units	Type	Number of units	Limiting resources	Discounted total returns
60	Hogs 2 - litters	1.6	Family living	$4460	Capital tenant	Landlord:
98.5			Corn Buying[a]	322 bu.	Land A	$4760[b]
21.4			Corn Disposal[c]	4413 bu	Land B	
39.6			Capital Transfer[b]		Corn Feed	Tenant:
.4			Hay Selling[a]	111 tons		$4443
9.3	Hogs 2 - litters	3.3	Family living	$4460	Capital tenant	Landlord:
50.7			Corn Selling[a]	4919 bu	Capital landlord	$3630[b]
39.6			Corn Disposal[b]	926 bu	Land A	
37.2					Land B	Tenant:
82.8						$3838
.4						

contribution is $577 per year and tenant's is $1000 in year 2 and $500 in year 3. Besides, the total returns of a shown in table 35 are reinvested in the farm in year 2. The latter amount to $6004.

rd's corn in disposal is included in this amount.

Table 38. Optimum tenant 5th and 6th year plan for a 220-acre farm under a customary crop-share leasing arrangement in capital of $5,250

		Optimum Combination of Enterprises						
		Crop rotation			Livestock		Other activities	
Year of plan	Discounted operating capital[a]	Type of land	Rotation	Acres	Type	Number of units	Type	Number of units
4	Landlord: $577	A	Corn$^{A}_{2,1,4}$	60	Hogs 2 - litter	3.4	Family living	$4,460
		B	Corn$^{B}_{1,1,4}$	2.6			Hay selling[c]	76 tons
	Tenant: $5,635	B	Corn$^{B}_{1,2,4}$	37.3			Corn disposal landlord	2962 bu
		B	Oats$^{B}_{2,2,4}$	37.3				
		B	Meadow$^{B}_{2,2,4}$	82.6				
5	Landlord: $577	A	Oats$^{A}_{2,1,4}$	60	Hogs 2 - litter	3.6	Family living	$4,460
		B	Corn$^{B}_{2,2,4}$	82.6			Hay selling[c]	34 tons
	Tenant: $5,968	B	Oats$^{B}_{2,1,4}$	2.6			Corn selling[c]	3763 bu.
		B	Oats$^{B}_{2,2,4}$	37.3			Corn disposal landlord	1170 bu.
		B	Meadow$^{B}_{2,2,4}$	37.3			Capital landlord disposal	$243

[a]Landlord's contribution is $577 per year. Tenant's contribution consists of gross returns of the previous year.

[b]The discounted value of the landlord's corn in disposal is included in this figure.

lan for a [illegible]-acre farm under a customary crop-share leasing arrangement in southwestern Iowa with a total operating

	Optimum Combination of Enterprises						
ies		Livestock		Other activities			
on	Acres	Type	Number of units	Type	Number of units	Limiting resources	Discounted total returns
3	60	Hogs 2 - litter	3.4	Family living	$4,460	Capital landlord	Landlord:
				Hay selling[a]	76 tons	Capital tenant	$3,410[b]
4	2.8					Corn tenant	
				Corn disposal		Land A	
4	37.3			landlord	2982 bu.	Land B	Tenant: $3,968
4	37.3						
2,4	82.6						
	60	Hogs 2 - litter	3.6	Family living	$4,460	Capital tenant	
	82.6			Hay selling[a]	34 tons	Land A	Landlord: $3,451[b]
	2.8			Corn selling[a]	3763 bu.	Land B	
	37.3			Corn disposal landlord	1170 bu.		Tenant: $4,103
,4	37.3			Capital landlord disposal	$243		

r. Tenant's contribution consists of gross returns of the previous year.

corn in disposal is included in this figure.

are more than 40 acres of oats and 37 acres of meadow. This indicates that as capital is becoming more scarce and as returns and yields decrease due to the depletion of the soil, activities such as oats and meadow which require relatively less capital and suffer less the impact of erosion on yields are considered by the tenant. This represents a change from his preferences of the first years when mostly corn and soybeans were selected in the optimal plans.

The livestock activities are constituted only by two-litter hog systems which do not increase in a significant way their scale of operation.

Other activities included in the optimum plan are hay selling, corn selling and, as usual, family living. A new activity which comes into the plan is landlord's capital disposal. This happens in the last year when the tenant's relatively low level of capital does not provide to the landlord enough opportunity of investment in crop activities.

The level of discounted returns attained by the tenant in year 5 is $4,105, almost $2,000 lower than in year 3. The landlord's share of $3,630 is also considerably lower than the $4,968 of year 3.

D. Optimal Long and Short Term Farm Plans with Tenant's Variable Capital

One of the hypotheses to be tested in this study expressed the importance of the level of capital in intra- and inter-temporal resource allocation. The optimal farm plans presented below permit us to gain insight into an interesting and somewhat obscure area of research.

The variable capital programming technique used in this study is described in full elsewhere (9, Chapter 8). This method is applied to our dynamic programming model in spite of the computational difficulties involved in handling a problem of such magnitude.

1. <u>A tenant six-year optimum plan with variable capital</u>

In Table 39 a summary of the most important features of the optimal six-year plans for a tenant-operated farm under a crop-share leasing arrangement is presented. The same institutional and resource restrictions affecting the tenant's six-year optimum plan shown in Section A of this same chapter were used in this plan. The activities and input-output coefficients were also identical to those of that plan.

The tenant's first year capital is varied from $5,500 to $7,500. These amounts do not represent the tenant's total operating capital. The latter also includes $1,000 in each of years 1 and 2 and $500 in year 3. Therefore, the tenant's total discounted value of operating capital is really varied from $7,000 to $9,000. The landlord's capital is not varied. It stays fixed at a discounted value of $577 per year.

A brief inspection of Table 39 reveals that there are activities whose level increases in a monotonic way, that is, they increase as capital is varied until a maximum level determined by resource restrictions is attained. This is the case of livestock activities such as 1) two-litter hog systems appearing each year in most of the plans and 2) medium and choice yearling steers. The latter activities which, contrariwise to hogs, require no building space, are included in the optimum plan only when the livestock building space capacity has been exhausted by the hog activities. This happens in the last years of some plans when hogs attain 20 units. This also requires that capital be accumulated over time and that there be a rather high level of total operating capital

Table 39. Levels of selected activities in tenant's 6-year optimum plan for a share-rented 240-acre farm in southwestern Io
capital supply

Tenant's operating year	Activity	$7000	$7250	$7500	$7750	Total Capital[a] $8000	$8135	$8250
		Level[b] of selected activities of optimum plan at different amounts of tenan						
0	$CCOMM^{A}_{2,1,0}$	60	60	60	60	60	60	60
0	$COM^{B}_{2,1,0}$	56.5	69.7	94.4	121.7	148.9	126.4	15.2
0	$COM^{B}_{2,2,0}$	-	-	-	-	-	33.5	144.6
0	Hogs 2 - litters	1.9	2.1	2.5	2.9	3.4	3.6	3.8
0	Corn buying	-	-	-	-	-	-	-
0	Land B disposal	103.5	90.2	65.6	38.3	11.0	-	-
1	$COM^{B}_{2,2,1}$	103.7	90.3	65.9	38.8	11.6	.1	-
1	Hogs 2 - litters	2.0	2.5	3.9	5.5	7.1	7.9	8.4
1	Corn selling	1966	2005	1942	1861	1779	1750	1761
1	Hay selling	287	298	319	341	364	375	383
2	Hogs 2 - litters	.7	1.1	3.2	5.6	6.0	9.0	9.6
2	Corn selling	3278	3166	2742	2228	1739	1533	1494
3	$COM^{B}_{2,2,3}$	56.6	69.7	94.6	121.8	149	33.5	15.3
3	Hogs 2 - litters	3.2	3.4	6.2	9.5	12.7	14.4	15.4
3	Corn selling	2747	2694	2116	1443	778	465	305
3	Corn buying	-	-	-	-	-	-	-
3	Hay selling	365	364	352	376	375	375	378

[a]The landlord's capital is fixed at $577 per year.

[b]Crop activities are expressed in acres, hogs in litters, cattle in a per head basis, corn selling and buying in bushels

...in tenant's 6-year optimum plan for a share-rented [illegible]-acre farm in southwestern Iowa with variable tenant's operating

	Total Capital[a]								
	$7250	$7500	$7750	$8000	$8135	$8250	$8494	$8750	$9000
	Level[b] of selected activities of optimum plan at different amounts of tenant's operating capital								
	60	60	60	60	60	60	60	60	60
.5	69.7	94.4	121.7	148.9	126.4	15.2	2.6	168	122.5
	-	-	-	-	33.5	144.6	157.1	51.8	37.2
.9	2.1	2.5	2.9	3.4	3.6	3.8	4.4	4.9	5.5
	-	-	-	-	-	-	102	263	320
.5	90.2	65.6	38.3	11.0	-	-	-	-	-
.7	90.3	65.9	38.8	11.6	.1	-	-	-	-
0	2.5	3.9	5.5	7.1	7.9	8.4	9.1	9.8	10.6
	2005	1942	1861	1779	1750	1761	1618	1383	1218
	296	319	341	364	375	383	383	374	373
.7	1.1	3.2	5.6	6.0	9.0	9.6	10.7	11.7	12.8
	3166	2742	2228	1739	1533	1494	1236	1004	776
6	69.7	94.6	121.8	149	33.5	15.3	2.8	168	122
8	3.4	6.2	9.5	12.7	14.4	15.4	17	16.2	19.6
	2684	2218	1443	778	465	305	-	-	-
	-	-	-	-	-	-	-	283	579
	384	382	376	375	375	378	377	372	371

...377 per year.

...es, hogs in litters, cattle in a per head basis, corn selling and buying in bushels and hay in tons.

Table 59 (Continued).

Tenant's operating year	Activity	Total Capital[a] $7000	$7250	$7500	$7750	$8000	$8135
		Level[b] of selected activities of optimum plan at different amounts of					
4	$CCOM^A_{2,1,4}$	45.6	50.6	60	60	30.5	0
4	$COM^A_{2,2,4}$	-	-	-	-	29.5	60
4	Land A disposal	14.4	9.3	-	-	-	-
4	$CCM^B_{2,2,4}$	103.6	90.4	65.8	38.6	11.5	.3
4	Hogs 2 - litters	-	-	5.9	9.0	13.0	14.7
4	Medium yearling steers	-	-	-	-	-	-
4	Livestock space disposal	1000	1000	807	551	348	257
4	Corn selling	3418	3434	2654	1643	1727	-
4	Corn buying	-	-	-	-	-	-
5	$CCOM^A_{2,1,5}$	14.4	9.3	-	-	-	-
5	Hogs 2 - litters	-	-	9.9	13.3	16.9	20
5	Choice yearling steers	-	-	-	-	-	-
5	Livestock space disposal	1000	1000	672	336	57	-
5	Labor disposal	553	553	455	394	239	174
5	Corn selling	3183	3279	2119	737	-	556
5	Corn buying	-	-	-	-	-	-
5	Hay selling	378	381	364	360	333	-
5	Landlord's discounted returns	$3,852	$4,072	$4,614	$5,186	$5,739	$6,111
5	Tenant's discounted returns	-	$2,250	$4,690	$7,712	$10,359	$11,636

				Total Capital[a]				
7250	$7500	$7750	$8000	$8125	$8250	$8494	$8750	$9000
evel[b] of selected activities of optimum plan at different amounts of tenant's operating capital								
50.6	60	60	30.5	0	34.4	60	7.6	-
-	-	-	29.5	60	25.6	-	52.4	60
9.3	-	-	-	-	-	-	-	-
50.4	65.8	38.6	11.5	.3	-	-	-	-
-	3.9	9.0	13.0	14.7	17.3	19.5	20	20
-	-	-	-	-	-	-	-	.5
1000	600	551	346	267	132	21	-	-
3434	2694	1643	1727	-	-	-	-	-
-	-	-	-	-	74	1506	757	601
9.3	-	-	-	-	-	-	-	-
-	9.9	13.3	16.9	20	20	20	20	20
-	-	-	-	-	7.9	12.9	14.2	17.3
1000	672	336	97	-	-	-	-	-
553	455	334	239	174	165	152	86	53
3273	2119	737	-	536	-	-	-	-
-	-	-	-	-	976	1328	732	617
351	354	350	333	-	357	359	279	264
4,072	$4,614	$5,166	$5,739	$6,111	$5,906	$5,866	$6,082	$6,109
2,250	$4,690	$7,712	$10,359	$11,636	$12,279	$13,393	$14,304	$15,124

in year 0. For instance, medium yearling steers come into the plan only in year 4 and at the highest level of operating capital, i.e., $9,000. Choice yearling steers are selected only in year 5 starting at $8,250 of operating capital.

Activities like corn selling and corn buying proceed in a different way as operating capital increases. Take for instance year 0. According to the model, corn is not sold until the beginning of the next year (only oats can be used in year 0) as livestock feed. When capital is scarce for the tenant, most of it is allocated to family living and crop activities and not much is left for hog enterprises. These activities require a considerable amount of capital. Hence, the level of hog activities is low in year 0, i.e., at $7,000 of capital there are 1.9 units of hogs. Only when total operating capital approaches $8,500 does a corn buying activity appear in the optimum plan and the level of hog enterprises has an opportunity to be increased.

Corn selling activities are selected in the following five years of the $7,000 optimum plan. In all cases, however, the amount of corn sold does not increase monotonically as the tenant's operating capital is varied. Corn selling usually goes up as capital levels increase and after reaching a peak it diminishes and disappears from the optimum plan giving way to the corn buying activity. This happens in years 3, 4 and 5 and is explained by the higher level of livestock activities which consume corn in larger amounts.

The hay selling activity is the only one which remains relatively stable as capital is varied. It is not much affected by changes in the livestock activities; the latter do not require a large amount of hay.

2. <u>The behavior of crop activities with variable capital</u>

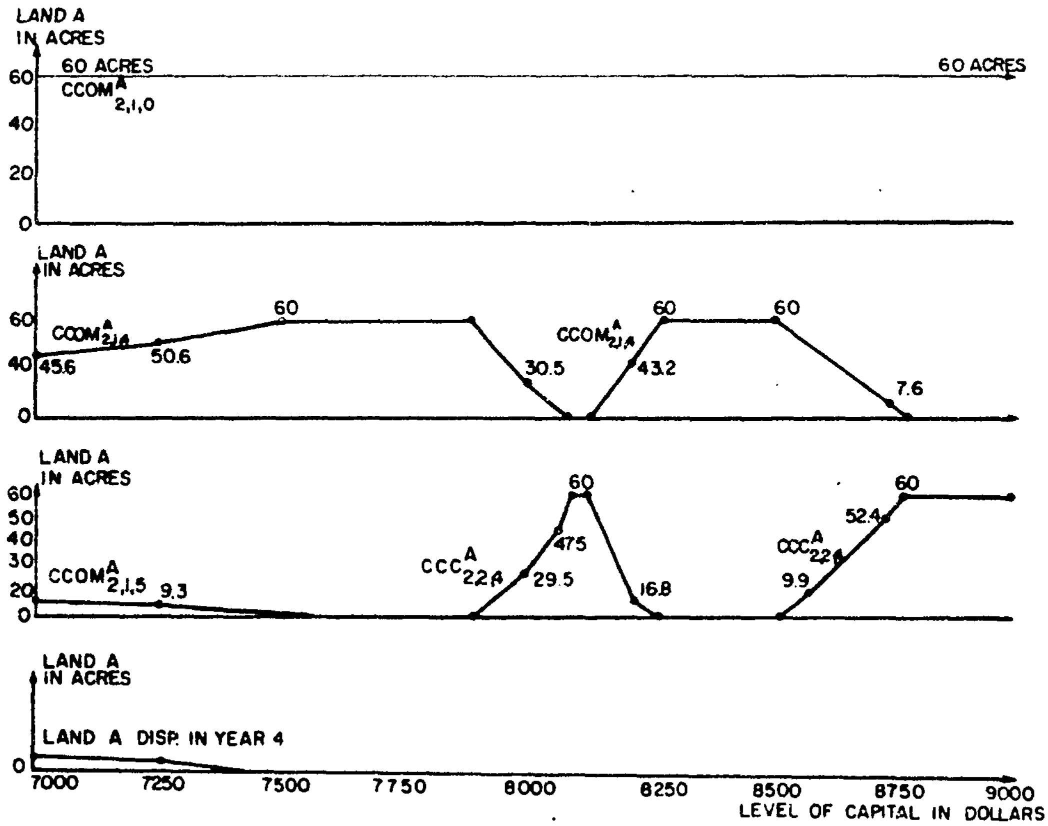
The crop activities are crucial in our study. The impact of planning horizon on the rate of investment can be assessed mostly through them. The variable capital technique offers new information when applied in a dynamic framework. The results shown below are of analytical interest.

At the outset it should be said that crop activities act in a different way from all other activities when capital is varied. As the latter increases certain crop activities increase their acreage in the optimal plan but after arriving at a peak they start to decline until they disappear from that plan. For instance, $COM^B{}_{2,1,0}$ and $CCOM^A{}_{2,1,4}$ as shown in Table 39 proceed in this manner.

This could be very well explained by the fact that the specific crop activity, as capital increases, is substituted by other crop activity for which the marginal return is higher as expressed in the criterion row $z_{jk}-d_{jk}$. However, a surprising finding is that the same crop activity which went out of the optimal plan at a specific level of capital comes in again at a higher level and replaces the activity which in its turn had replaced itself when capital was lower. This behavior of crop activities is hard to explain. In order to attempt an explanation it is necessary to examine the behavior not only of crops but also of all other activities. This is what we intend to do in the remainder of this section.

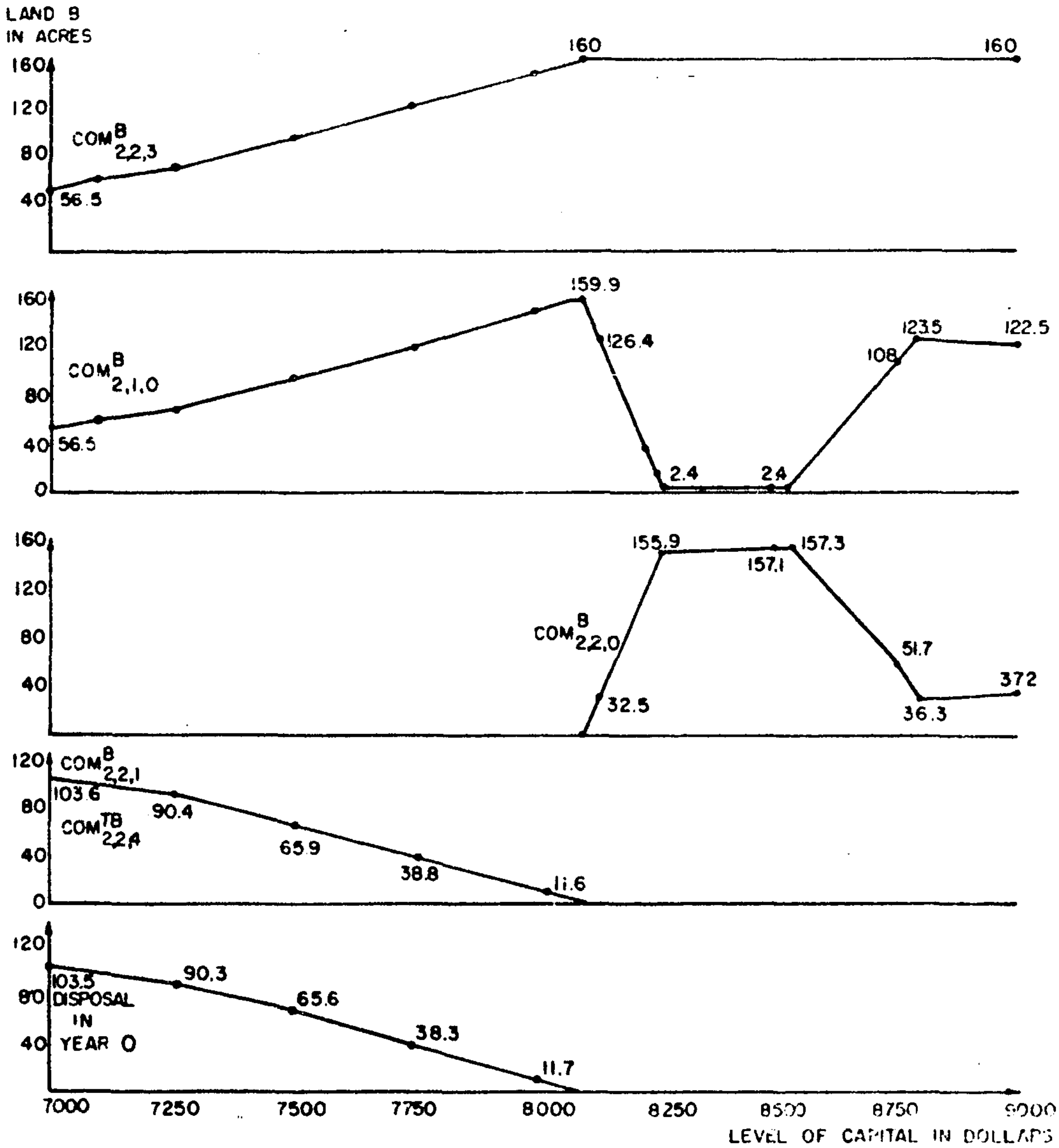
Figures 10 and 11 illustrate the behavuor of all crop rotations included in the optimal plan at different levels of capital. For convenience, let us classify them in "well behaved" and "bad behaved"

Figure 10. Behavior of Land A rotations as capital is increased in tenant's six-year optimal plans



LAND A IN ACRES
60 ACRES
$CCOM^A_{2,1,0}$
60 ACRES
60
40
20
0
LAND A IN ACRES
$CCOM^A_{2,1,4}$
45.6
50.6
60
30.5
$CCOM^A_{2,1,4}$
43.2
60
60
7.6
LAND A IN ACRES
60
50
40
30
20
0
$CCOM^A_{2,1,5}$
9.3
$CCC^A_{2,2,4}$
29.5
47.5
60
16.8
$CCC^A_{2,2,4}$
9.9
52.4
60
LAND A IN ACRES
LAND A DISP. IN YEAR 4
0
7000
7250
7500
7750
8000
8250
8500
8750
9000
LEVEL OF CAPITAL IN DOLLARS

Figure 11. Behavior of Land B rotations as capital is increased in tenant's six-year optimal plans


LAND B
IN ACRES
160
120
80
40
COM B 2,2,3
56.5
160
160
159.9
126.4
COM B 2,1,0
56.5
2.4
2.4
108
123.5
122.5
0
COM B 2,2,0
32.5
155.9
157.1
157.3
51.7
36.3
372
COM B 2,2,1
103.6
COM TB 2,2,4
90.4
65.9
38.8
11.6
103.5
DISPOSAL
IN
YEAR 0
90.3
65.6
38.3
11.7
7000
7250
7500
7750
8000
8250
8500
8750
9000
LEVEL OF CAPITAL IN DOLLARS

activities. In Land A as shown by Figure 10, $CCOM^{A}_{2,1,0}$, $CCOM^{A}_{2,1,5}$ and Land A disposal in year 4 are "well behaved". The first appears occupying the same acreage, 60 acres, at all levels of capital. $CCOM^{A}_{2,1,5}$ and Land A disposal monotonically decreases as capital increases until they disappear from the optimal plan.

The "bad behaved" activities in Land A are $CCOM^{A}_{2,1,4}$ and $CCC^{A}_{2,2,4}$. Figure 10 illustrates well how the activities change and displace each other as capital increases from $7,800 to $8,750.

If we use the same criterion to classify the crop activities of Land B we find that $COM^{B}_{2,2,3}$, $COM^{B}_{2,2,1}$, $COM^{TB}_{2,2,4}$ and Land B disposal in year 0 are "well behaved" and that $COM^{B}_{2,1,0}$ and $COM^{B}_{2,2,0}$ are "bad behaved" activities. These last two displace each other and come in again into the optimum plan in the $8,000 - $8,750 range.

The fact that the levels of capital of the bad behaved period of activities of both Land A and B approximately coincide gives us our first hint. The behavior of these activities may be traceable to the effect of a common factor or factors.

If the behavior of other activities in that same range of capital is examined, the following appears to be relevant to our problem. Livestock activities increase in all years; in years 4 and 5 they reach the limit imposed by the restrictions of 20 units of 2-litter hogs; corn buying in years 4 and 5 as well as choice yearling steers in year 5 are the new activities coming into the optimal plan; all corn selling activities leave the optimal plan in the range of capital considered.

All these factors permits us to give a hypothetical explanation of the behavior of crop activities as capital increases. The crux of the matter is that as the level of livestock activities increases more capital and corn is needed. If the level of capital is varied above \$8,000, $CCC^A_{2,2,4}$ comes into the optimal plan. This activity provides corn in year 5 and the hogs can be increased from 13.3 units to 18.9 at the \$8,000 level of capital. Corn selling in year 5 goes out of the optimal plan at the same level.

However, the new activity $CCC^A_{2,2,4}$ consumes a large amount of capital. The balance must be restored by producing more corn and consequently returns in the first four years. Hence the change from $COM^B_{2,1,0}$ to $COM^B_{2,2,0}$ in year 0. Even if the first consumes more capital in year 0 than the second one, this switch of rotations is understandable due to the fact that the variable capital row is year 0's capital row and therefore more capital is available in the first year. The additional corn produced from $COM^B_{2,2,0}$ permits to increase the level of livestock activities in the first four years and consequently raise the capital supply in year 4 in order to finance the extra capital investment in terraces of $CCC^A_{2,2,4}$.

The introduction of a new activity in year 5, that is choice yearling steers, starts a new wave of adjustments in the allocation of capital resources. $CCC^A_{2,2,4}$ which competes for capital with this new activity, begins to decline beyond the \$8,100 capital level in order to permit the activity to come into the optimal plan. The decline of $CCC^A_{2,2,4}$ and the added consumption by yearling steers produces a deficit of corn. Two new activities come into the optimal plan in years 4 and 5; corn buying activities which balance the corn supply available for livestock.

As the level of capital goes beyond \$8,500 the more-capital-consuming $CCC^{A}_{2,2,4}$ which had gone out of the optimal plan comes in again displacing the less-capital-consuming $CCOM^{A}_{2,1,4}$. The imbalance in capital in years 4 and 5 is compensated by the gradual disappearance of $COM^{B}_{2,2,0}$ in year 0 and its replacement by $COM^{B}_{2,1,0}$. The latter consumes less capital and permits that more of the latter be allocated to livestock enterprises which raise the capital supply of years 4 and 5. In these last two years as the level of $CCC^{A}_{2,2,4}$ increases more corn is available. Consequently in year 4 the corn buying activity starts to decline beyond \$8,250 of capital because in that year the units of hogs do not increase and no extra corn is consumed. In year 5 the corn buying activity stays stable because choice yearling steers increase constantly at those levels of capital.

Thus, we have presented a possible explanation for the behavior of certain crop rotations in the optimal plans as capital is varied. There is no pretention that this is the only explanation. It rather has the character of a tentative hypothesis which should be tested by further research.

3. <u>A tenant's two-year optimum plan with variable capital</u>

Table 40 presents a summary of the main features of an optimal two-year plan for a tenant under customary crop-share leasing arrangements. The same institutional and resource restriction affecting the tenant in the two-year optimal plan shown in Table 35, Section C, of this chapter were used in this model. However, there are some differences. This is a more imperfect model because it possesses less flexibility in the crop activities. It uses as activities-two year rotations instead of single

Table 40. Levels of selected activities in tenant's 2-year optimum plan for a share-rented 220-acre farm in (

operating capital supply

Tenant's operating year	Activity	Tenant's capital in year 0[a]					
		$5500	$5750	$6000	$6250	$6500	$6750
		Level[a] of selected activities of optimum plan at different amounts of te					
0	$C^A_{2,1,0}$	60	60	60	60	60	6
0	$C^B_{1,1,0}$	40.9	60.1	76.1	93.2	109.7	122.7
0	$C^B_{2,1,0}$	26.3	28.3	30.6	32.9	35.2	37
0	$C^B_{1,2,0}$						
	$H^B_{2,0,0}$	92.8	71.6	52.8	34	15.2	.33
0	Hogs 2 - litters	.01					.11
0	Family living	4460	4460	4460	4460	4460	4460
0	Corn Buying	13					23
0	Hay Selling	259	200	148	95	42	.88
1	$SB^A_{2,1,1}$	60	60	60	60	60	60
1	$SB^B_{2,1,1}$	26.3	28.3	30.6	32.9	35.2	37
1	$SB^B_{1,2,1}$						
1	$C^B_{1,1,1}$						
1	$O^B_{1,1,1}$	40	40	40	40	40	40
1	$H^B_{2,0,1}$	92.8	71.6	52.8	34	15.2	.33
1	Hogs 2 - litters		.4	.9	1.3	1.7	2.3
1	Family living	4460	4460	4460	4460	4460	4460
1	Corn selling[b]	3364	3686	3958	4231	4504	4656

enant's 2-year optimum plan for a share-rented 220-acre farm in southwestern Iowa with variable tenant's

Tenant's capital in year 0[a]									
$5750	$6000	$6250	$6500	$6750	$7000	$7250	$9895	$12250	$14950
f selected activities of optimum plan at different amounts of tenant's operating capital									
60	60	60	60	60	60	60	60	60	60
60.1	76.1	93.2	109.7	122.7	60.8	47.7	40	52.2	63.5
28.3	30.6	32.9	35.2	37	1.9			27.1	40.2
					96.9	111.2	93.4	22.1	
71.6	52.8	34	15.2	.33	.38	1.1	26.6	58.6	56
				.11	.59	1.11	3.8	13.6	20.0
4460	4460	4460	4460	4460	4460	4460	4460	4460	4460
				23	119	224.	1278	2764	4956
200	148	95	42	.88	.82	2.7	72	159	149
60	60	60	60	60	60	60	60	60	60
28.3	30.6	32.9	35.2	37	1.9			27.1	40.2
					96.9	111.2	93.4	22.1	
						7.7		12.8	23.5
40	40	40	40	40	40	40	40	40	40
71.6	52.8	34	15.2	.33	.38	1.1	26.6	58.6	56.0
.4	.9	1.3	1.7	2.3	2.6	3.3	8.5	20	20
4460	4460	4460	4460	4460	4460	4460	4460	4460	4460
3686	3958	4231	4504	4686	4632	4504	2604		

Table 40. (continued)

Tenant's operating year	Activity	Tenant's capital in year 0[a]						
		$5500	$5750	$6000	$6250	$6500	$6750	$
		Level[b] of selected activities of optimum plan at different amounts of te						
1	Corn disposal[c]	3364	3770	4133	4495	4858	5144	5
1	Hay selling	259	200	147	94	42		
1	Labor disposal	437	339	251	164	76	4	
1	Capital selling							
1	Landlord's discount returns	4429	4343	4260	4176	4093	4027	4
	Tenant's discount returns	2486	3079	3640	4200	4760	5284	5

[a] The landlord's capital is fixed at $577 per year.

[b] Crop activities are expressed in acres, hogs in litters, cattle in a per head basis, corn sellin

Tenant's capital in year 0[a]									
$5750	$6000	$6250	$6500	$6750	$7000	$7250	$9295	$12260	$15292
lected activities of optimum plan at different amounts of tenant's operating capital									
3770	4133	4495	4858	5144	5158	5167	4652	4056	4131
200	147	94	42			1.8	70	156	149
339	251	164	76	4					
									4062
4343	4260	4176	4093	4027	4243	4278	4352	4335	4275
3079	3640	4200	4760	5284	5668	6030	8973	13233	17096

3577 per year.

res, hogs in litters, cattle in a per head basis, corn selling and buying in bushels and hay in tons.

crops. Consequently, it does not permit a rotation starting at a specified level of fertilization to change in the second year to a higher or lower level.

The tenant's first year capital is varied from $5,500 to $7,500. The total level of capital includes $1,000 additional in year 1 for the tenant and $577 each year for the landlord.[1] The landlord's capital is not varied.

A brief survey of Table 40 indicates that here as in the previous plan with variable capital we have again some crop activities which behave in a rather unorthodox way. These are $C^B_{2,1,0}$, $M^B_{2,1,0}$ and $C^B_{1,1,0}$ in year 0 and $Sb^B_{2,1,1}$ and $M^B_{2,0,1}$ in year 1. The first three are illustrated in Figure 13.

We do not intend to explain the behavior of these activities in the same detail as in the previous section. Let us only say that here a new factor enters into the picture besides capital and corn. This is labor of year 1 which becomes limiting beyond the $6,750 level of capital. This explains, we believe, the remarkable shift towards meadow which occurs at the higher levels of capital in this plan.

It is interesting to compare briefly this plan with the corresponding one in Table 35. The level of returns is slightly larger for the latter. The crops selected are approximately the same and also the rate of fertilization of those same crops. What differs considerably between

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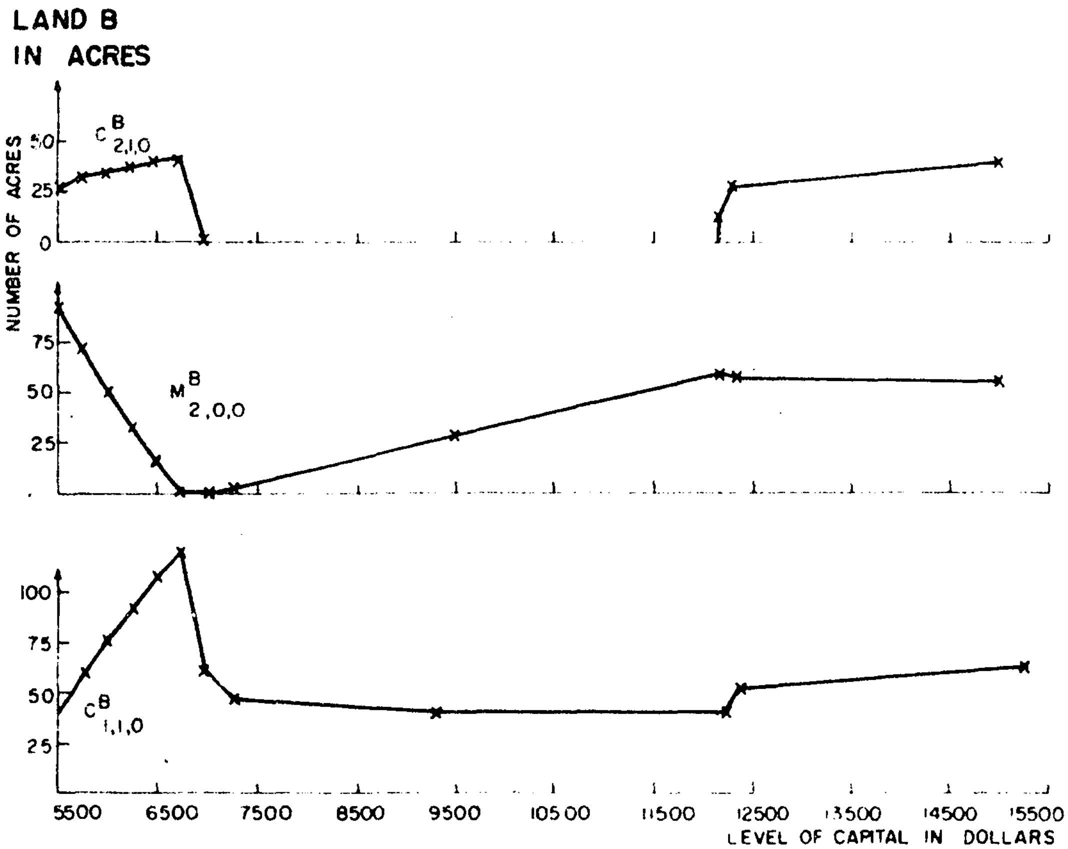
[1] If we were to compare this plan with the one in Table 35, we must look here at the $6,750 level.

Figure 12. Behavior of Land B crops in two-year tenant's optimal plans with variable capital


LAND B
IN ACRES
NUMBER OF ACRES
$C^B_{2,1,0}$
50
25
0
$M^B_{2,0,0}$
75
50
25
100
75
50
25
$C^B_{1,1,0}$
5500
6500
7500
8500
9500
10500
11500
12500
13500
14500
15500
LEVEL OF CAPITAL IN DOLLARS

the two plans is the amount of terraced land. In the other optimal plan 56.8 percent of Land B is terraced, whereas in this plan not a single acre is terraced. Only when capital increases crops with terraced land comes into the optimal appear in the optimal plan.

The significance of these results (as well as the other presented in this chapter) with regard to the hypotheses which are tested in this study will be considered in the next chapter.

VI. INTERPRETATION OF EMPIRICAL RESULTS

Having dealt with other objectives of this study in the previous chapter we turn not to one of its major ones, that is, to measure inter-temporal inefficiencies within a lease and to identify the factors responsible in creating the gap between an ideal situation or norm and the actual situation.

This chapter provides an answer to these questions. In doing so, the four hypotheses derived in Chapter II evaluating the theory of leasing systems and the state of empirical research in that field will be taken one by one. The empirical results shown in the previous chapter provide material to test these hypotheses. The economic analysis presented below follows the order in which the four hypotheses were presented earlier.

A. Inter-temporal Inefficiencies in Crop-Share Leases

The first hypothesis states that an inadequate planning horizon engendering uncertainty of tenure, caused by short-term leasing arrangements, produces an inefficient inter-temporal resource allocation and affects the nature of profitable investment. In order to measure these inefficiencies the level of returns for a farm after a six-year lease contract should be compared with that for the same farm after three consecutive two-year leases.

According to Table 32 the firm's total discounted returns in the terminal year of the tenant's optimal six-year plan amount to $18,183. Of these, $12,275 corresponds to the tenant's returns and $5,908 to the landlord's.

In Table 38 the firm's total returns in the terminal year of the three consecutive tenant's optimal two year plans are $7,556, of which $4,105 corresponds to the tenant and $3,451 to the landlord.

The difference in total returns between the two situations amounts to $10,627. This means that a firm operating under a crop-share arrangement with an adequate planning horizon for the tenant obtains $10,627 more of discounted returns than a second firm under the same economic and institutional restrictions but with a tenant's planning horizon limited by the leasing arrangement to a two year period.

This gap between the two plans can be attributed to inter-temporal inefficiencies. If the farmer had a longer term of lease or a compensation clause for the earning potential of unexhausted investments he would have been motivated to allocate his resources in a different manner. We can conclude about the situation considered in this study that certainty of association of costs and benefits for the tenant permits him to maximize his capital and other resources in the long-run after having met his yearly consumption needs.

In Table 41 more detail is given concerning the change over time or discounted total returns for both landlord and tenant in each of the situations described above. It can be seen that in the first year the returns for the firm - and individually for landlord and tenant - are greater under the short-term lease than the longer-term lease. The firm obtains that year in the first case $10,239 whereas under a six-year lease it only earns $5,263. In the second and third year something similar occurs although the gap between long and short-term leases becomes closer, returns in one and other case are $9,880 and $8,847 versus $10,972 and $9,203.

In the fourth year the situation is reversed: the long-term plan's returns, $10,760, are slightly higher than those of the short-term ones, $9,468. This trend continues in the last two years when the gap between the long and short-term plan becomes considerable.

In Figure 13 the difference in discounted returns for landlord and tenant in both plans is illustrated. This figure shows some interesting features. For instance, in year 3 there is a noticeable change in the trend of the landlord's discounted returns in the short-term plan. For the first time the landlord's returns are less than the tenant's. This could be explained by the fact that the fertility of the soil has been depleted considerable in the first three years and the impact of the reduction of yields is felt in the fourth and later years. The tenant's returns, however, do not decrease as much because he allocates more capital resources to livestock activities which are not affected by the decrease in yields of crop rotations.

In the last year the difference in discounted total returns between short and long-term plans is $10,627. This might look too wide a gap between the two plans. However, if we consider the assumptions of our model, this difference does not seem unjustified. In effect, short and long-term plans are discounted for uncertainties by the same risk premium. If the longer-term plans were discounted by heavier discount factors than short-term plans, then the gap in returns between the two plans would not look so great.

Table 13. Discounted total returns for landlord and tenant's optimal plans under long and short-term leases

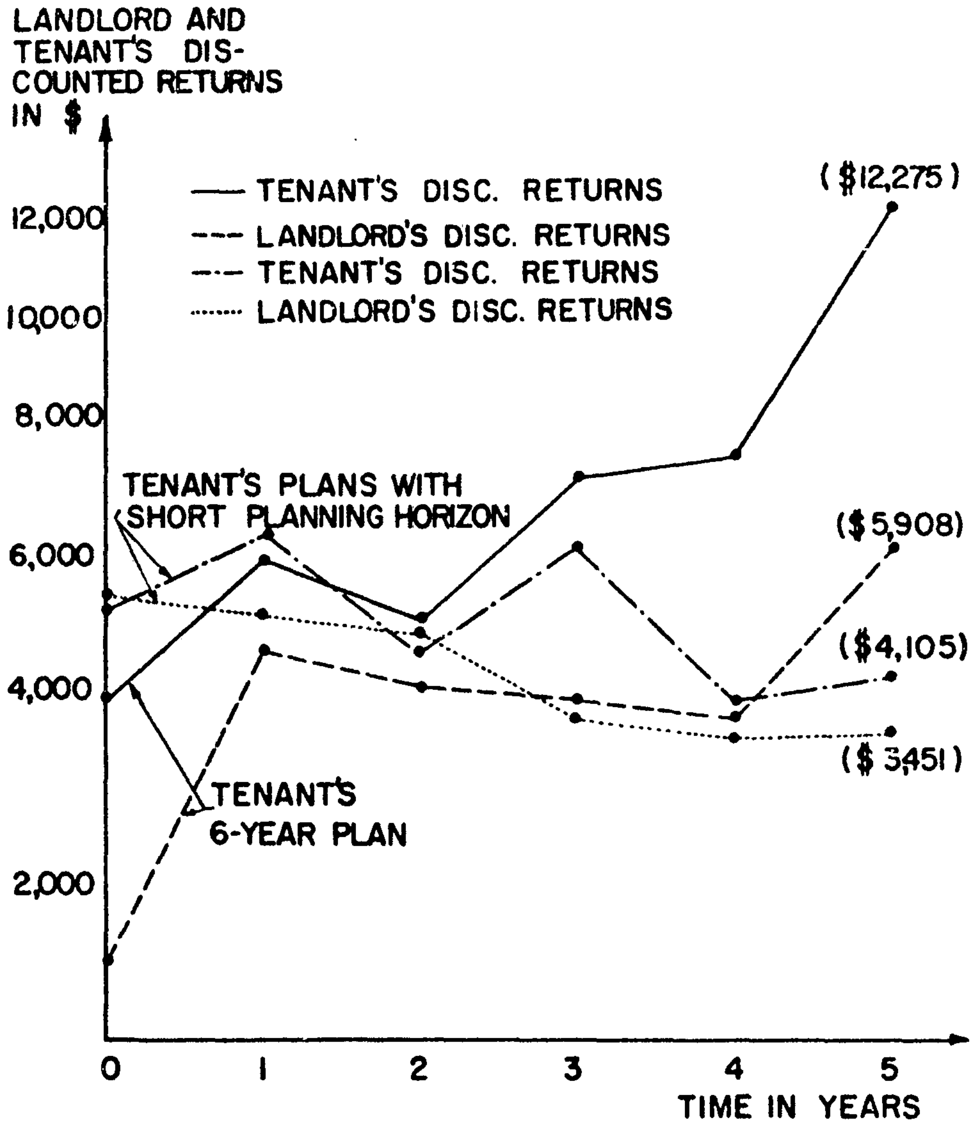

LANDLORD AND TENANT'S DIS- COUNTED RETURNS IN $
TENANT'S DISC. RETURNS
LANDLORD'S DISC. RETURNS
TENANT'S DISC. RETURNS
LANDLORD'S DISC. RETURNS
12,000
10,000
8,000
6,000
4,000
2,000
($12,275)
($5,908)
($4,105)
($3,451)
TENANT'S PLANS WITH SHORT PLANNING HORIZON
TENANT'S 6-YEAR PLAN
0
1
2
3
4
5
TIME IN YEARS

Table 41. Discounted returns over a 6-year period for a tenant with and without adequate planning horizon

Year	Long-term leases			Short-term leases			Firm's
	Landlord's	Tenant's	Firm's	Landlord's	Tenant's	Firm's	Difference
	Discounted total returns			Discounted total returns			
0	$1,372	$ 3,891	$ 5,263	$5,181	$5,058	$10,239	-$ 4,976
1	$4,222	$5,658	$ 9,880	$4,968	$6,004	$10,972	-$ 1,092
2	$4,029	$ 4,818	$ 8,847	$4,760	$4,443	$ 9,203	- $ 356
3	$3,869	$ 6,891	$10,760	$3,630	$5,838	$ 9,463	+$ 297
4	$3,668	$ 7,370	$11,038	$3,410	$3,968	$ 7,378	+$ 3,660
5	$5,908	$12,275	$18,183	$3,451	$4,105	$ 7,556	+$10,627

Table 42 gives a summary of the percentage of different crops in each year of the optimum plan for a tenant subject to long and short-term leases. Inspection of the selection of crops in the two alternative plans shows that under short-term leasing arrangements there is a tendency towards soil depletion. The proportion of corn and soybeans is relatively greater than that of meadow and oats in short-term leasing arrangements.

The latter is particularly true for crops grown on Land A. It can be noticed that under short-term leases 100 percent of Land A is grown with corn or soybeans whereas under a long-term lease only 50 percent of the Land A has corn. The remainder of the land under the last type of lease is divided in equal proportion between oats and meadow.

With regard to Land B there is also a tendency under short-term leases towards more corn crops than under a long-term lease.[1] This is particularly true of the first years, because in year 4 the percentage of Land B in corn is only 25 percent in the tenant's optimal plan under short-term leases and 33.3 percent under long-term leases. This, however, reverses the trend only for that year. In year 5 again the first type of leasing arrangement seems to encourage the cultivation of more corn.

Thus we can conclude that our first hypothesis can be accepted on the basis of empirical results. There is ample evidence that, under the assumptions of this inquiry, an inadequate planning horizon on the part of a tenant under customary crop-share leasing arrangements produces inter-

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[1]We must not forget that all rotation activities in the long-term plan contain oats and meadow. Therefore these results are less significant for Land B than for Land A, which has some rotation with a low proportion of oats and meadow or even with nothing but corn.

Table 42. Percentage acreage of different crops appearing in tenant's optimal plan with adequate and inadequate planning horizon

Year		Short-term leases Corn	Soybeans	Oats	Meadow	Long-term lease Corn	Oats	Meadow
		LAND A						
0	Acres	59.9	-	-	-	30	15	15
	%	100.0	-	-	-	50	25	25
1	Acres	60	-	-	-	30	15	15
	%	100.0	-	-	-	50	25	25
2	Acres	60	-	-	-	30	15	15
	%	100.0	-	-	-	50	25	25
3	Acres	9.3	50.7	-	-	30	15	15
	%	15.5	84.5	-	-	50	25	25
4	Acres	60	-	-	-	23.8	18.1	18.1
	%	100.0	-	-	-	39.7	30.1	30.1
5	Acres	60	-	-	-	23.8	18.1	18.1
	%	100.0	-	-	-	39.7	30.1	30.1
		LAND B						
0	Acres	159.6	-	.4	-	53.3	53.3	53.3
	%	99.8	-	.2	-	33.3	33.3	33.3
1	Acres	-	129.6	30	.4	53.3	53.3	53.3
	%	-	81.0	18.8	.2	33.3	33.3	33.3
2	Acres	119.9	-	-	40	53.3	53.3	53.3
	%	74.9	-	-	25	33.3	33.3	33.3
3	Acres	76.8	-	82.8	.4	53.3	53.3	53.3
	%	48.0	-	51.8	.2	33.3	33.3	33.3
4	Acres	40.1	-	37.3	82.6	53.3	53.3	53.3
	%	25.1	-	23.3	51.6	33.3	33.3	33.3
5	Acres	82.6	-	40.1	37.3	53.3	53.3	53.3
	%	51.6	-	25.1	23.3	33.3	33.3	33.3

temporal inefficiencies in resource allocation and alters the nature of profitable investment.

B. Effect of Planning Horizon on Investment in Fertilizer, Equipment and Conservation Practices

The second hypothesis states that a tenant with short planning horizon, caused by short-term leases without compensation clauses for unexhausted improvements, is not motivated to invest in fertilizer, buildings and equipment and in conservation practices. Consequently, the rate of investment in the above items should prove lower for such a tenant than for one having an adequate planning horizon.

In order to determine whether to accept or reject this hypothesis, the results presented in the previous chapter are analyzed further in respect to this hypothesis.

1. Investment in fertilizer in short and long-term leases

To assess the impact of planning horizon on investment in fertilizer it was necessary to find an index of fertilizer use. We have considered that the most convenient one for our purposes is the percentage of land acreage in the optimal plans using a high level of fertilization under short and long-term leasing arrangements. Table 43 presents the results of our analysis.

It is interesting to note that the effect of planning horizon on the rate of fertilization in Land A is non-existent. In effect, under both types of leases the optimal plans provide for a 100 percent of total Land A acreage using the highest level of fertilization. This is explained by the fact that Land A in the area studied has a slope of 1 to 4 percent and

Table 43. Investment in fertilizer in optimal tenant's plans with adequate and inadequate planning horizon

	Short-term leases						Long-term leases					
	Land A			Land B			Land A			Land B		
Year	Acres fert.[a]	Total acres	%	Acres fert.[a]	Total acres	%	Acres fert.[a]	Total acres	%	Acres fert.[a]	Total acres	%
0	59.9	59.9	100	.4	160	.2	60	60	100	159.9	159.9	100
1	60	60	100	30.4	160	19.0	60	60	100	159.9	159.9	100
2	60	60	100	61.4	160	38.4	60	60	100	159.9	159.9	100
3	60	60	100	160	160	100	60	60	100	159.9	159.9	100
4	60	60	100	119.9	160	74.9	60	60	100	159.9	159.9	100
5	60	60	100	157.2	160	89.2	60	60	100	159.9	159.9	100

[a]High level of fertilization

is quite productive. Hence, the marginal returns of fertilizer are large in this type of land and capital is allocated in a preferential way to crop activities in Land A which use a high level of fertilization. This is true even in the case of tenants with inadequate planning horizon.

In Land B things occur differently. Here there is a marked difference in the rate of fertilization investment made by a tenant with adequate or inadequate planning horizon. In the case of the short-term lease the percentage acreage at a high level of fertilization is much lower than in the case of a long-term lease. This is illustrated by Figure 14. The percentage acreage of Land B at a high level of fertilization in the tenant's optimal plan is measured in the vertical axis and time in years in the horizontal axis.

Under a short-term lease the percentage of Land B using a high level of fertilization in the optimal plan is only .25 percent in year 0 against 100 percent in the other type of lease. In the second and third year the difference is also quite remarkable: 19 and 38.4 percent versus 100 percent in the two years. Only in year 3 all Land B appears at a high level of fertilization in the optimum plan for a short-term leasing arrangement. In the last two years 74.9 and 98.2 percent of Land B is highly fertilized under a short-leasing optimal plan. Under a long-term lease the optimal plan still includes a 100 percent of Land B at high rates of fertilization.

The above can be explained by the fact that Land B which has a slope of 8 to 12 percent is less productive than Land A and therefore the marginal productivity of capital invested in fertilizer in this type of land must be lower than in Land A or than in other activities like livestock. Capital resources which are scarce particularly in the first three years

Figure 14. Percentage acreage of Land B at a high level of fertilization in tenant's short and long-term optimal plans

are not allocated in great quantities to crop activities grown in Land B and therefore these do not come into the optimum plan at a high level of fertilization unless some activities like meadow which consume relatively less capital occupy a significant proportion of the total acreage. The latter occurs only in the longer-term leasing arrangements as we saw in the previous section. In the short-term leases, at least in the first years, a much higher proportion of high capital consuming activities like corn and soybeans appear in the optimal plan and consequently the use of high fertilization rates is done in a much smaller scale.

We can then conclude that the second hypothesis concerning investment in fertilizer is acceptable only with respect to Land B. In Land A the rate of fertilization is independent of the length of horizon of the tenant.

2. Investment in buildings and equipment in short and long-term leases

Due to the fact that in our models the expansion of fixed resources is not considered, we cannot assess the effect of planning horizon on the rate of investment in buildings and other fixed equipment. There is one exception, however, livestock equipment. In effect our model permits livestock equipment to increase over time by the inclusion of a restriction in each year except the first.[1]

If the optimal six-year plan for the tenant is examined and compared to the three consecutive two-year plans for the same tenant, it can be inferred that the longer-term leasing arrangement encourages a larger

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[1]We refer back to Chapter III in which this is explained in detail.

investment in livestock equipment than the short-term arrangement.

The difference in the value of investment in livestock equipment is quite remarkable when the two plans are compared. It can be explained partly by the fact that in the longer-lease optimal plan more low-capital-consuming meadow is selected in the first year contributing thus to free the scarce capital resources that can be allocated to livestock enterprises. In the optimal plans under short-term leasing arrangements most of the capital resources are allocated in the first years to high-c apital-consuming enterprises like corn or soybeans.

3. Investment in terracing in short and long-term leases

Investment in terracing as it is affected by the tenant's planning horizon can be assessed by the same criterion we have used before in the case of fertilizer investments. This criterion is the percentage of terraced land in the total acreage of the optimal plans for the tenant with short and long-term leases.

Table 44 presents the percentage of Land A and B which is terraced as appearing in the optimal plans for the tenant under short-term leases and under a six-year lease. It can be seen from these results that there are differences between the two types of leases with respect to percentage of terraced land. Under a short-term lease the optimal plan for the tenant has 56.8 percent of Land B with terraces in the first year against 90.4 percent under a long-term lease. The situation remains unchanged until the third year when the percentage of Land B with terraces increases to 61.6 in the tenant's optimum under a short-term lease. In the fourth year this same plan includes 75 percent of Land B terraced whereas the six-year plan increases to a 100 percent of Land B with terracing. In the

Table 44. Investment in terracing in tenant's optimal plans with adequate and inadequate planning horizon

	Short-term lease			Long-term lease		
Year	Acres Terraced	Total Acres	%	Acres Terraced	Total Acres	%
			Land A			
0	-	60.0	-	-	60.0	-
1	-	60.0	-	-	60.0	-
2	-	60.0	-	-	60.0	-
3	-	60.0	-	-	60.0	-
4	-	60.0	-	5.6	60.0	9.3
5	-	60.0	-	5.6	60.0	9.3
			Land B			
0	90.9	160.0	56.8	144.6	160.0	90.4
1	90.9	160.0	56.8	144.6	160.0	90.4
2	98.5	160.0	61.6	144.6	160.0	90.4
3	120.0	160.0	75.0	159.9	159.9	100.0
4	157.2	160.0	98.3	159.9	159.9	100.0
5	160.0	160.0	100.0	159.9	159.9	100.0

last two years the percentage of terraced land is practically the same for the two leases.

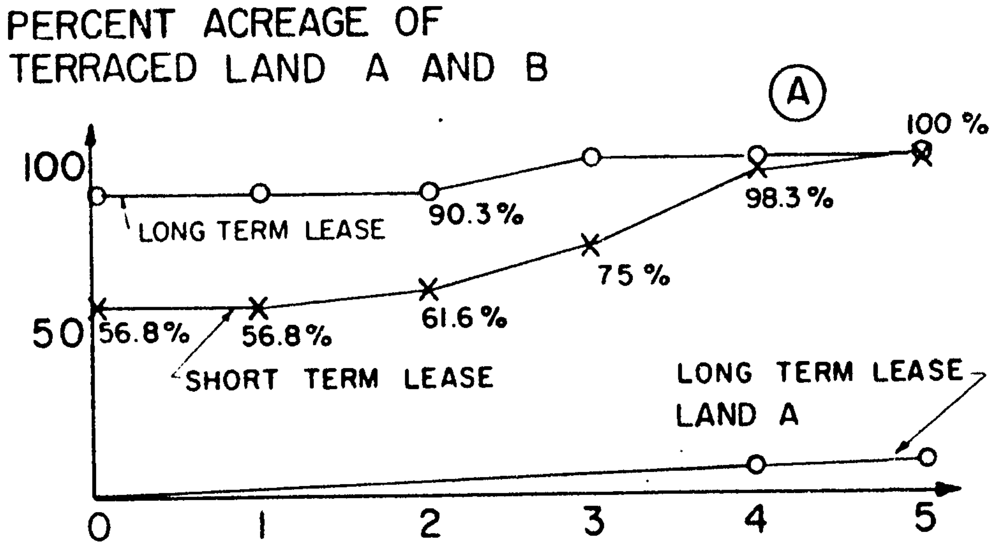
The short-term optimal plans do not include any crop activity which uses terraces in Land A. The long-term optimal plan includes some but only in the last two years and in a reduced scale. In year 4 and 5, 9.3 percent of Land A is cultivated on terraces.

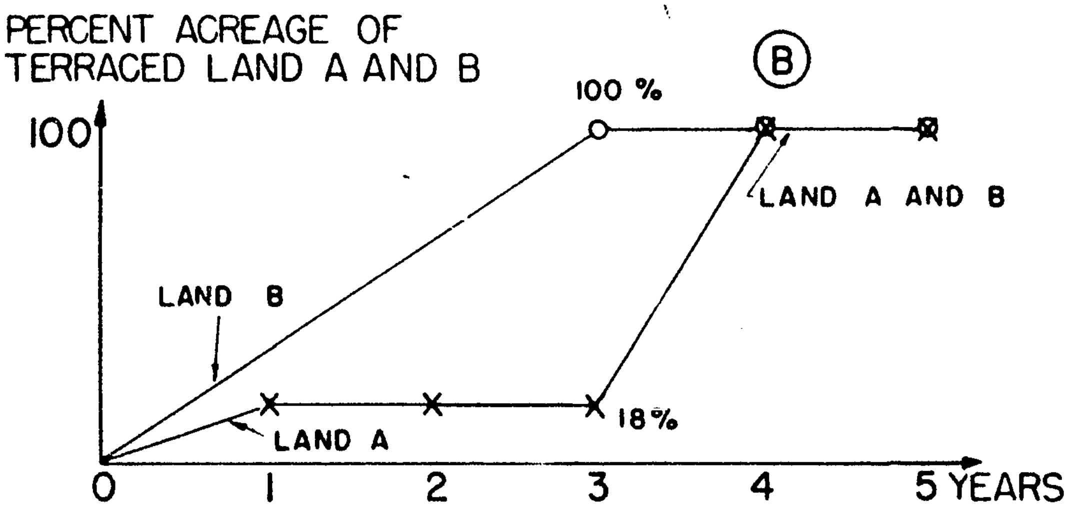
The characteristics of the terraced percentage of Land A and Land B under the two types of leases can be better understood perhaps by means of Figure 15 A. It is clear that the rate of investment in terracing under the two alternative leasing differs in some respects and in others presents certain similarities.

For instance, the pattern of change over time of terraced land assumes a similar form in the two classes: under both types of leases the percentage of terraced land increases monotonically over time; both start in year 0 at a positive level of terracing; both attain given time a 100 percent of total Land B with terraces. The main difference between the two classes is the acceleration of the rate of increase of terraced Land B over time. In the short-term arrangements the percentage of terraced Land B increases at a slower rate than in the six-year leasing arrangement.

We will consider only in passing the optimum six-year plan for the landlord. We find considerable differences between this plan and the corresponding six-year optimal plan for the tenant. The percentage of Land A which is terraced is quite large as shown in Figure 15 B. In the last two years it attains 100 percent of all Land A. This is quite different from the tenant's optimal plan in which there is only 9.3 percent of Land A terraced in these two years.

Figure 15. Percentage acreage of terraced Land A and B in optimal plans under short and long-term leases and in landlord's optimal six-year plan


PERCENT ACREAGE OF
TERRACED LAND A AND B
A
100
50
100 %
90.3%
98.3%
LONG TERM LEASE
75 %
56.8%
56.8%
61.6%
SHORT TERM LEASE
LONG TERM LEASE
LAND A
0
1
2
3
4
5


PERCENT ACREAGE OF
TERRACED LAND A AND B
B
100 %
100
LAND A AND B
LAND B
18%
LAND A
0
1
2
3
4
5 YEARS

It can also be noticed that the allocation of resources takes a different form in the tenant's six-year optimum and the landlord's. This difference in resource allocation is caused, as we have briefly mentioned above, by intra-temporal inefficiencies. In a customary crop-share lease, among other things, the unequal sharing of products violates the second incentive condition. In particular returns of livestock enterprises are not shared by landlord and tenant in the same proportion as other enterprises like crops. This explains the difference in the rate of fertilization and conservation as shown in Figure 15 B and in the previous tables.

We can conclude, with respect to the part of hypothesis two studied in this section that short-term leases, that is those limiting the planning horizon of the tenant, slow down considerably the rate of investment in terraces in Marshall soils whose slope is rather steep and which are consequently subject to erosion.

In the case of flat land such as Land A, the effect of an inadequate planning horizon on terracing investment seems to be less clear cut. The results obtained in this inquiry do not furnish enough evidence in support of the hypothesis that short-term leases affect significantly the rate of investment in terraces in that soil type. Further research could clarify this point.

C. Effect of Capital Resources on the Rate of Investment in Fertilizer, Equipment and Terracing

The third hypothesis states that the relationships between the restrictions in the amount of landlord's and tenant's capital supply and the sharing of costs and returns have also an impact on the rate of investment of the tenant in fertilizer, building and equipment, and in the use of terracing.

In this section we will examine the different parts of this hypothesis. The relationships between the landlord and tenant's capital and the sharing of costs and returns will be considered in the light of the empirical results of our dynamic models. Then, the impact of a change in the tenant's capital supply of the first year on the rate of investment in fertilizer and conservation practices will be analyzed.

1. Landlord and tenant's capital in relation to sharing of costs and returns: its impact on the rate of investment over time

That the amount of the tenant's and landlord's capital supply in relation to the sharing of costs and returns has an impact on economic efficiency has already been established by other studies like the Heady-Egbert and the Timmons-De Benedictis (13, 5). These studies have shown that the dissociations of costs and benefits engendered by certain customary clauses of crop-share leases, e.g., the sharing of oats in a 60:40 basis while other crops are shared in a 50:50 basis, etc., produce intra-temporal inefficiencies in resource allocation.

These studies, however, have not assessed the impact of these customary provisions in a dynamic framework, that is over time. A way of doing so is provided by the optimal plans presented in the previous chapter. In particular, the two first six-year optimal plans for the tenant and the landlord should be examined (Tables 32 and 33).

It is important to keep in mind that the level of capital is fixed in these two optimal plans. The landlord contributes $3,460 in the six-year period and the tenant $8,250 including there the amount for family consumption. The conclusions which we may obtain from this analysis are therefore only applicable to situations comparable to those of the optimal plans not only in terms of physical and institutional restrictions but also in terms of the capital level selected for the above mentioned plans. This level of capital, it could be said in passing, is perhaps a little above the average one for farms in the area of our study.

Figures 15 A and B show how these two plans differ with respect to investment in terraces. There is a higher proportion of Land A with terraces in the landlord's optimum than in the tenant's

A second difference between the two plans is the proportion of the different crops selected. In the tenant's optimal plan there is much more land in oats and meadow than in the landlord;s optimal plan. This effect seems to be accentuated over time. For instance, Land A in the last two years has a 100 percent of corn whereas in the tenant's optimal plan it has only 39.7 percent. The remainder of Land A is in the last plan occupied by oats and meadow in equal proportion.

A third difference between the landlord and tenant's optimum lies in the investment over time in livestock enterprises. For instance, in the last year the landlord's optimal plan includes 20 units of 2-litter hogs and the tenant's optimal plan includes the same number of hog units plus 7.9 units of yearling steers.

All the above differences in resource allocation between the two optimal plans can be attributed to lease-engenered intra-temporal inefficiencies. The first and second differences between the two optimal plans are caused by violations of the first and second incentive conditions.

The customary sharing of oats and meadow are responsible for these inefficiencies. The third difference can be attributed to the unequal sharing of livestock products and other products as stipulated by the customary crop-share lease. Costs and returns in livestock enterprises are completely the concern of the tenant while other costs and returns of other products are shared by landlord and tenant.

The shift over time in the allocation capital resources in the tenant's optimal plan towards more oats and meadow and in the landlord's optimal plan towards more corn and soybeans, seems to indicate that lease-engendered intra-temporal inefficiencies are accentuated over time. The net effect over time of these inefficiencies appears to be a decrease in the rate of investment in terraces for Land A, that is for flat Marshall soils of good fertility.

In the case of livestock enterprises, the net effect of over time intra-temporal inefficiencies appears to be an increasement in the tenant's rate of investment.

2. Effect of increase in tenant's operating capital in the rate of investment in fertilizer, equipment and terracing

The acceleration of the rate of investment in fertilizer, equipment and conservation practices is usually considered a function of capital. This is true but requires several qualifications in the case of a tenant-operated farm under customary crop-share leasing arrangements. The rather surprising results of the two sets of optimal plans with tenant's variable capital presented in Section D of the last chapter have established this fact.

From these plans (Tables 39 and 40) it can be asserted that only in the case of livestock equipment the rate of investment is a monotonic increasing function of capital. In the case of investment in fertilization the statement seems less warranted by the empirical results although at high levels of capital it seems also to be true. In the case of terracing the empirical results do not show very clearly which is the relation between capital and the rate of investment.

The two-year optimal plan with tenant's variable capital shows that the percentage acreage under high fertilization seems to change upwards and downwards as capital varies. In more technical terms as capital increases and a new corner of the transformation curve is attained there is a reshuffling of resources that makes some activities come into the plan, stay there as capital increases, disappear from the plan when other activity with higher marginal revenue replaces them and finally come back again into the plan as capital increases further. Figure 12 illustrates this point in the case of $C^B_{2,1,0}$, $M^B_{2,1,0}$ and $C^B_{1,1,0}$; From these results it is difficult to establish the true nature of the effect of capital on fertilizer investment. The six-year optimal plan does not give much information because most of the rotation activities appear at a high rate of fertilization at all levels of capital considered.

There is a similar situation with regard to terracing: the six-year optimal plans with tenant's variable capital showin in Table 36 do not indicate a clear trend in the investment in terraces when capital is increased. Activities like $COM^B_{2,2,0}$ which require terraces come into the optimal plan and then are displaced by activities like $COM^B_{2,1,0}$ which do not require terracing as shown on Figure 11. It is true that at the highest levels of capital the trend in the two plans with variable capital hints towards more conservation (particularly in the six-year plan). It could happen, however, that at other levels of capital for the tenant and for the landlord this trend could be reversed or at least slowed down.

We can conclude from the above analysis that the hypothesis about the effect of capital on the rate of investment in fertilizer, equipment and terracing is not completely acceptable on the basis of our empirical results. It is acceptable for the case of investment in livestock equipment. In the other two cases more research is needed in order to understand better the effect of capital on inter-temporal allocation of resources.

What appears clear however is that the rate of investment in conservation practices and particularly in terraces is not a function, given the restrictions of this study and the price relationships, only of capital resources but also of the availability of other resources like corn, labor and land of different qualities, all of which are closely related to the profitability of livestock enterprises in a crop-share lease. The interrelationships between all these resources and capital, insofar the tenant maximizes returns of the terminal planning year, seem to determine the pattern of investment in terracing over time.

D. Increase in Efficiency in Crop-Share Leases

The last hypothesis states that if the previous hypotheses are accepted a customary crop-share lease could increase inter-temporal and intra-temporal efficiency by (a) adequate planning horizon assured by longer-term leases or in its defect by provisions in the lease of compensatory payments to the tenant according to the earning power of his unexhausted resources (b) by a better sharing of capital contributions of both landlord and tenant, and (c) by modification in the quantity of resources contributed by the two parties and in the sharing of products between them.

In reality this hypothesis is not directly tested by the empirical research undertaken in this study. It is a conditional hypothesis because its recommendations or suggested remedies to intra-temporal and inter-temporal inefficiencies caused *per se* by leasing systems have only relevance if the previous hypotheses, particularly the first and the third one, have proven to be acceptable on the evidence of the empirical results.

The first hypothesis was accepted on the basis of our results and it established that inter-temporal inefficiencies in customary crop-share leases were considerable in the situation studied. If these inefficiencies exist the way to eliminate them is by assuring the tenant association of costs and benefits. This would be obtained by providing him with longer-term contracts or, in the case of a short-term lease, by stipulating in the contract that he will be adequately compensated for the potential productivity of his investments in case of cessation of contract.

The second and third part of this last hypothesis aims at reducing intra-temporal inefficiencies which may be accentuated over time. An unequal sharing of expenses may produce inefficiencies as was established in the previous section. A way of avoiding these inefficiencies is suggested, namely a different and flexible basis in the sharing of expenses and consequently of products between landlord and tenant according to their financial capabilities. A periodical valuation of the resources contributed by each party and negotiation on the proportions of returns going to each party should prove successful to lessen the observed intra-temporal inefficiencies. This was discussed in certain detail in Chapter II, Section D, and its application and further testing seems to be warranted by the empirical results obtained in this study.

VII. SUMMARY AND RECOMMENDATIONS FOR FURTHER RESEARCH

A. Summary of This Inquiry

The first objective of this study was to develop a method of dynamic linear programming that permits the introduction of t years of activities and restrictions (t = 0, ... , n) in order to observe the effect of time on resource allocation in farms operated under different tenure systems.

A dynamic model was articulated which (a) meets the goals or ends-in-view of the agricultural entrepreneur, that is, maximization of total returns of the terminal year of his planning period; and (b) allows for a fixed yearly amount of family consumption. In particular, model for owner-operated farms and for crop-share rented farms under short and long-term leasing arrangements were presented in detail.

To this effect, a theoretical analysis of the Hicksian theory of the firm when applied to an agricultural set-up was made. A review of the main contributions to the theory of leasing systems followed by certain dynamic qualifications was presented. From this analysis a set of four hypothesis was obtained. These hypothesis were to be tested by results coming from an application of a dynamic model to an empirical case situation.

The next step of this study was to apply the dynamic model developed to a farm situation in order to assess the impact on economic efficiency of uncertainty of tenure caused by short-term leases. The farm selected for study as typical of the Marshall soil area of southwestern Iowa has 220 acres of tillable land of which 60 acres have 1 to 4 percent slope and the remainder 160 acres, 8 to 12 percent slope. Most of the resource and institutional restrictions were derived from the MINK data, a survey undertaken by the North Central Regional Land Tenure Committee, the United States Department of Agriculture, the Farm Foundation and four cooperating states, Missouri, Iowa, Nebraska and Kansas. The yield and fertilizer estimates were furnished by the Agronomy Department, Iowa State University. Likewise, information about livestock enterprises was provided by the Extension Service at Iowa State University. In the statistical phase of the study the Statistical Laboratory of the above-mentioned university cooperated.

A set of optimal farm plans for different tenure situations was obtained. These include six-year ex-ante optimal plans for owner-operators, landlords and tenants, employing alternative levels of fertilization, conservation and livestock investment. It is assumed that a six-year planning horizon is adequate for a tenant under a crop-share lease. Also, a set of three optimal and consecutive two-year plans covering the same period of time as the previous six-year plans is obtained.

Another series of tenant's six and two-year plans with variable capital is obtained. All the above results permits to study the effect of time on resource allocation. It can be seen that the optimal combination of enterprises is not the same under different tenure systems.

Also the impace of customary leasing arrangements on inter-temporal efficiency is analyzed. This is done by testing the four hypotheses derived from economic theory and from previous empirical results. The first hypothesis states that inter-temporal inefficiencies are attributable to the tenant's limited planning horizon in customary crop-share leasing arrangements. This hypothesis is accepted on the basis of the empirical results. The latter indicate that a tenant under short-term leases, which are common in the area studied, attains a considerably lower level of returns in the long-run than a tenant under a longer-term leasing arrangement.

The second hypothesis states that inadequate planning horizon for the tenant causes (a) a decrease in the rate of fertilizer application, (b) a decrease in the rate of investment in equipment and (c) a decrease in the rate of investment in conservation practices such as terracing. The results show that (b) is true in the case of livestock equipment. They further show that (a) and (c) are also acceptable in the case of the steeper soils. In flatter lands, however, the results do not indicate a clear difference between long and short-form leases.

The third hypothesis talks about the effect of the relative contributions of capital of landlord and tenant on the rate of investment. On the one hand, there is evidence that intra-temporal inefficiencies caused by inadequate sharing arrangements between landlord and tenant tend to be accentuated over time. On the other hand, results coming from the tenant's optimal plans at different levels of capital show that only in the case of livestock equipment investment is a monotonic increasing function of capital. In the case of fertilizer and terracing no clear relation between their rate of investment and the capital resources of the tenant is established. More research is needed to better understand the role of capital in inter-temporal allocation of resources.

The last hypothesis, conditioned to the acceptance of the three previous hypotheses, suggests some possible ways to remedy inter-temporal inefficiencies in leasing arrangements and also intra-temporal inefficiencies which are accentuated over time. The remedies are (a) adequate planning horizon assured by longer-term leases or by agreements satisfactory to both parties of compensating the tenant for potential earnings of improvements in case of cessation of contract, (b) a better sharing of expenses between landlord and tenant and (c) modification in the quantity of resources contributed by the two parties and in the sharing of products between them.

B. Recommendations for Further Research

This last section endeavors to give some recommendations for further research using our models and extending the results obtained in this study. In particular, the stress will be made, firstly, on the refinements of methods and, secondly, in the possibility of improving and complementing the results.

1. Improving the methods

When dealing with problems of such magnitude as the ones seen in this study, the greatest difficulties aee perhaps computational ones. It becomes then important to profit from the experience of previous research in order to simplify the computations and reduce the costs.

In this respect some recommendations can be made after completion of this study. What appears evident is that the simplex method needs some adaptations if we want to handle matrices of large dimensions. There are two or three ways of avoiding at least in part the excessive number of iterations that would occur if the electronic computer was left to run free, that is, using the ordinary criterion of selecting all the $z_{jk} - d_{jk}$ -.001.

The first way of avoiding excessive iterations consists of changing the criterion used in the program to select the incoming activities. For instance, it is possible to start running the problem by selecting only those columns with $z_{jk} - d_{jk}$ - 10 or even a higher negative figure if some disposal activity with a large -M value has been forced into the plan (e.g. family living). As the number of iterations decreases the criterion can again be changed this time downwards. This procedure is repeated until the regular value of -.001 is used and the optimal feasible solution is obtained.

Another way of avoiding excessive iterations is to use a-priori economic knowledge in obtaining the solution. If the researcher knows from previous experience that certain activities will never come into the optimal plan it pays in terms of time and money to simply eliminate them. For instance, in the long-term plans obtained in this study there is not a single crop activity coming into the optimal plan at a low level of fertilization or conservation. If more problems would be undertaken with regard to the same or similar empirical situations this fact should be kept in mind.

Another way of using a-priori economic knowledge consists of selecting a specific combination of crops and other activities which constitute in an economic sense a feasible solution. This solution even if not the optimal provides a basis which becomes a good starting point for arriving at the optimum. There is a method of preselecting by row and column in a computer a certain basis or plan which is successful in certain cases. From this plan sometimes only few iterations are needed to attain the optimum.

The procedure outlined above has the advantage of reducing rounding errors which may become serious if the number of iterations is sufficiently large. The accuracy of the results depends also on the coding. In this respect our experience is that the coding of the input-output coefficients, which are required to approach 1 in the program used for the IBM 650 of our study, does not have a great impact in the accuracy of the results. The coding of the P_o column, however, seems to have quite an effect on accuracy. With this respect the accuracy of the six-year plan for an owner-operator and for a tenant can be compared. The first plan, which was obtained first, is much less accurate due to the coding of the P_o by 1/1000. The second was coded only by 1/10 and gave more satisfactory results with respect to accuracy. In subsequent problems the P_o's were not coded even if this produced some complications due to overflows.

Finally, a point which should be stressed is that a good method of checking the coefficients may avoid time and money. A single error in the coefficients may oblige the researcher to run again a complete program.

2. <u>Extending the results of this research</u>

There are considerable ppssibilities of applying the models presented in Chapter III to different empirical situations that is to different soil areas and institutional restrictions in this and other countries.

In the case of the MINK data from which was drawn the bulk of the information used in our study, it could be possible to extend the same model to different soil areas of the four states included in the survey. As a complement to our research a more comprehensive study of the effect of tenant's variable capital on resource allocation over time could be undertakan. In particular, the impact on the rate of investment in conservation practices seems to present analytical interest.

Other studies that could possibly be undertaken making use of our dynamic models on the basis of the MINK data include an analysis of inter-temporal inefficiencies in other types of leases such as livestock and cash leases. Our model could also be used to study the effect of different price expectations on resource allocation. As well the effect of changing and flexible basis of sharing for tenant and landlord in crop-share and livestock leases is of interest.

This model for investigating inter-temporal inefficiencies in leasing systems could also be adapted for application in studying tenancy arrangements and tenure systems of other countries and in particular those of the under-developed countries. The main difficulty there would be the acquirement of accurate coefficients.

VIII. LITERATURE CITED

1. Bellman, Richard Ernest. Dynamic programming. Princeton, N. J. Princeton University Press, 1957.

2. Berry, Russell, L. and Bau, Vernon E. Tenant interest in long-term cash and flexible cash leases. South Dakota Agricultural Experiment Station, Bulletin 480. 1959.

3. Bronfenbrenner, M. Production functions: Cobb-Douglas, interfirm, intrafirm. Econometrica, 12:35-44. 1944.

4. Chryst, Walter E. and Timmons, John F. Adjusting farm rents to changes in prices, costs and production. Iowa Agricultural Experiment Station. Special Report No. 9. 1955.

5. De Benedictis, Michele and Timmons, John F. Linear programming in investigating intratemporal inefficiencies in leasing systems. Iowa Agricultural Experiment Station. Research Bulletin. (In process. 1961).

6. Dorfman, Robert, Samuelson, Paul A. and Solow, Robert M. Linear programming and economic analysis. New York. McGraw-Hill Book Co., Inc. 1958.

7. Griliche, Zvi. Specification bias in estimates of production functions. Journal of Farm Economics. 39:8-20. 1957.

8. Grosvenor, Dale David. Large matric programs for an electronic computer with limited storage. Unpublished M.S. Thesis. Ames, Iowa. Library, Iowa State University of Science and Technology. 1960.

9. Heady, Earl O. Economics of agricultural production and resource use. Englewood Cliffs, N. J. Prentice Hall, Inc. 1952.

10. Heady, Earl O. Economics of farm leasing systems. Journal of Farm Economics. 29:659-678. 1947.

11. Heady, Earl O. Marginal productivity of resources and imputation of shares for cash and share rented farms. Iowa Agricultural Experiment Station. Research Bulletin 433. 1955.

12. Heady, Earl O. and Candler, Wilfred. Linear programming methods. Ames, Iowa. Iowa State College Press. 1958.

13. Heady, Earl O., Dean, Gerald W. and Egbert, Alvin C. Analysis of the efficiencies of alternative farm leasing arrangements. (An application of linear programming). Iowa Agricultural Experiment Station. Research Bulletin 445. 1956.

14. Heady, Earl O. and Kehrberg, Earl W. Relationship of crop-share and cash leasing systems to farming efficiency. Iowa Agricultural Experiment Station. Research Bulletin 386. 1952.

15. Heady, Earl O., Mackie, Arthur B. and Stoneberg, Everett G. Plans for beginning farmers in southwest Iowa with comparison of farm and nonfarm income opportunities. Iowa Agricultural Experiment Station. Research Bulletin 456. 1958.

16. Held, R. Burnell and Timmons, John F. Soil erosion control in process in western Iowa. Iowa Agricultural Experiment Station. Research Bulletin 460. 1958.

17. Hicks, J. R. Value and capital. 2nd ed. Oxford. At the Clarendon Press. 1953.

18. Hill, Howard L. and Staniforth, Sydney D. A modification of leasing arrangements to expand farm opportunities. Wisconsin Agricultural Experiment Station in Cooperation with United States Department of Agriculture. Research Bulletin 213. 1959.

19. Hurlburt, Virgil L. Farm rental practices and problems in the Midwest. Iowa Agricultural Experiment Station. Research Bulletin 416. 1954.

20. Hurlburt, Virgil L. Property taxes and insurance premiums as fixed costs in farm valuations and rental determinations. Journal of Farm Economics. 41:821-829. 1959.

21. Iowa Department of Agriculture, Division of Agricultural Statistics. Iowa Crop and Livestock Reporting Service. Jan.-Dec. 1955-1959.

22. Irwin, George David. Effects of pork production technique on optimum farm resource use. Unpublished M.S. Thesis. Ames, Iowa. Library, Iowa State University of Science and Technology. 1959.

23. Johnson, Glenn L. Problems in studying resource productivity and size of business arising from managerial process. In Heady, Earl O., Johnson, Glenn L., and Hardin, Lowell S. eds. Resource productivity, returns to scale and farm size. pp. 16-23. Ames, Iowa. The Iowa State College Press. 1956.

24. Loftsgard, Laurel D. and Heady, Earl O. Application of dynamic programming models for optimum farm and home plans. Journal of Farm Economics. 41:51-62. 1959.

25. Miller, Walter G., Chryst, Walter E. and Ottoson, Howard W. Relative efficiencies of farm tenure classes in intrafirm resource allocation. Iowa Agricultural Experiment Station. Research Bulletin 461. 1958.

26. Plaxico, James S. Problems of factor-product aggregations in Cobb-Douglas value productivity analysis. Journal of Farm Economics. 37:664-675. 1955.

27. Reder, Melvin W. An alternative interpretation of the Cobb-Douglas function. Econometrica. 11:259-264. 1943.

28. Smith, Wesley G. and Heady, Earl O. Use of dynamic model in programming optimum conservation farm plans on Ida-Monona soils. Iowa Agricultural Experiment Station. Research Bulletin 475. 1960.

29. Timmons, John F. Economic framework for watershed development. Journal of Farm Economics. 36:1170-1183. 1954.

30. Timmons, John F. Improving agricultural tenancy. Rome. Food and Agriculture Organization of the United Nations. Agricultural Studies 35. 1957.

31. Timmons, John F. Improving farm rental arrangements in Iowa. Iowa Agricultural Experiment Station. Research Bulletin 393. 1953.

32. Timmons, John F. Integration of law and economics in analyzing agricultural land use problems. Journal of Farm Economics. 37: 1126-1142. 1955.

33. Timmons, John F. Land institutions impeding and facilitating agricultural adjustment. In Problems and policies of American agriculture. Assembled and published under the sponsorship of the Iowa State University Center for Agricultural Adjustment. pp. 166-188. Ames, Iowa. Iowa State University Press. 1959.

34. Tinbergen, J. The notions of horizon and expectancy in dynamics economics. Econometrica. 1:247-264. 1933.

35. Tintner, Gerhard. Econometrics. New York. John Wiley and Sons, Inc. 1952.

36. Tintner, Gerhard. Game theory, linear programming and input-output analysis. Zeitschrift fur Nationalokonomie. 17:1-38. 1957.

37. Toussaint, W. D. Two empirical techniques applicable to land tenure research. Journal of Farm Economics. 37:1354-1363.

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X. APPENDICES

A. HOUSEHOLD CONSUMPTION

Family consumption is a part of the tenant's fixed costs. The latter also include $938.27 for machinery depreciation, $150 for personal property tax and $275 for income tax.

The household consumption items include, apart from food, clothes, household operations and repairs and furnishing, $729 for health insurance and medical items and $282 for miscellaneous items such as recreation, education, charity and others.

The landlord pays $275 for income tax, $670.80 for real estate taxes. The owner-operator pays $250 for income tax, $670.80 for real estate taxes apart from the same household and other fixed costs as the tenant.

B. YIELD AND FERTILIZER ESTIMATES

Table 18. Estimated first and second year crop yields for various levels of conservation and fertilization

	Land A[a]								
Practices:	Conservation			Contouring			Terracing		
Fertilizers:	No	Low	High	No	Low	High	No	Low	High
	N P	N P	N P	N P	N P	N P	N P	N P	N P
Rotation									
Corn$_0^b$	43	48	63	45	50	65	48	53	68
Oats$_1$	30	35	42	30	35	42	33	38	45
Corn$_0^b$	43	48	63	45	50	65	48	53	68
Soybeans$_1$	20	24	26	22	25	27	23	26	28
Meadow$_0^b$	2.2	2.5	3.2	2.2	2.5	3.2	2.2	2.5	3.2
Corn$_1$	43	48	68	48	53	72	48	53	72
Meadow$_0$	2.2	2.5	3.2	2.2	2.5	3.2	2.2	2.5	3.2
Meadow$_1$	2.2	2.5	3.2	2.2	2.5	3.2	2.2	2.5	3.2
Corn$_1^b$	43	48	63	45	50	65			

[a]Low-medium fertilization practices in 1958 and 1959. Assume that rotation was CCOMM or COM.

[b]10 pounds K_2O on all high corn.

Table 18(Continued)

Practices:	Land B[a]								
	Conservation			Contouring			Terracing		
Fertilizers	No N P	Low N P	High N P	No N P	Low N P	High N P	No N P	Low N P	High N P
Rotation									
Corn$_0^b$	32	34	47	34	37	50	40	42	56
Oats$_1$	20	25	32	21	26	33	24	29	36
Corn$_0^b$	32	34	47	34	37	50	40	42	56
Soybeans$_1$	17	18	20	17	18	20	20	21	22
Meadow$_0^b$	2.0	2.2	2.8	2.0	2.2	2.8	2.1	2.3	3.0
Corn$_1$	30	35	48	33	38	52	38	42	57
Meadow$_0$	2.0	2.2	2.8	2.0	2.2	2.8	2.1	2.3	3.0
Meadow$_1$	2.0	2.2	2.8	2.0	2.2	2.8	2.1	2.3	3.0
Corn$_1^b$	32	34	47	34	37	50			

Source: John T. Pesek and Frank F. Riecken, Agronomy Department, Iowa State University. Private communication. Feb. 22. 1960.

Table 19. Estimated third and fourth year crop yields for various levels of conservation and fertilization

Conservation:	Land A[a]								
	No practices			Contouring			Terracing		
Fertilizers:	No	Low	High	No	Low	High	No	Low	High
	N P	N P	N P	N P	N P	N P	N P	N P	N P
After C$_1$									
Corn$_2$	40[b]	45	63	42	47	65	45	50	68
Corn$_3$	37[b]	42	63	39	44	65	42	47	68
Corn$_2$	40	45	63	42	47	65	45	50	68
Soybeans$_3$	19	23	25	21	24	26	22	25	27
Corn$_2$	40	45	63	42	47	65	45	50	68
Oats$_3$	30	35	42	30	35	42	33	38	45
Oats$_2$	30	35	42	30	35	42	33	38	45
Meadow$_3$	2.2	2.4	3.0	2.2	2.4	3.0	2.2	2.4	3.0
After M$_0$M$_1$									
Corn$_2$	50	55	69	55	60	74	55	60	74
Soybeans$_3$	20	24	26	22	25	27	23	26	28
Corn$_2$	50	55	69	55	60	74	55	60	74
Corn$_3$	45	50	68	50	55	72	50	55	72
After C Sb									
Corn$_2$	40	45	63	42	47	65	45	50	68
Corn$_3$	39	42	63	39	44	65	42	47	68
Corn$_2$	40	45	63	42	47	65	45	50	68
Soybeans$_3$	19	23	25	21	24	26	22	25	27

[a] Low-medium fertilizer practices in 1958 and 1959

[b] 10 pounds K_2O on all high corn

Table 19 (Continued)

Conservation:	Land B[a]								
	No practices			Contouring			Terracing		
Fertilizers:	No N P	Low N P	High N P	No N P	Low N P	High N P	No N P	Low N P	High N P
After C_1									
$Corn_2$	30	32	45	31	34	48	35	39	54
$Corn_3$	28	30	43	28	31	46	30	37	53
$Corn_2$	30	32	45	31	34	48	35	39	54
$Soybeans_3$	16	17	19	16	17	19	19	20	21
$Corn_2$	30	32	45	31	34	48	35	39	54
$Oats_3$	20	25	32	21	26	33	24	29	36
$Oats_2$	20	25	32	21	26	33	24	29	36
$Meadow_3$	2.0	2.2	2.7	2.0	2.2	2.7	2.1	2.3	2.8
After M_0M_1									
$Corn_2$	36	41	54	39	44	57	42	47	60
$Soybeans_3$	17	18	20	17	18	20	20	21	22
$Corn_2$	36	41	54	39	44	57	42	47	60
$Corn_3$	33	38	50	36	41	53	39	44	58
After C Sb									
$Corn_2$	30	32	45	31	34	48	35	39	54
$Corn_3$	28	30	43	28	31	46	30	37	53
$Corn_2$	30	32	45	31	34	48	35	39	54
$Soybeans_3$	16	17	19	16	17	19	19	20	21

John T. Pesek and Frank F. Reicken, Agronomy Department, Iowa State University. Private Communication Feb. 22, 1960

Table 20. Estimated fifth and sixth year crop yields for various levels of conservation and fertilization

Conservation:	Land A[a]								
	No practices			Contouring			Terracing		
Fertilizers:	No N P	Low N P	High N P	No N P	Low N P	High N P	No N P	Low N P	High N P
After CCC$_3$									
Corn$_4$	30	35	63	32	37	65	35	40	68
Corn$_5$	20	35	63	32	37	65	35	40	68
or CCC Sb									
Corn$_4$	30	35	63	32	37	65	35	40	68
Soybeans$_5$	18	22	25	20	23	26	21	24	27
or CSb CSb									
Corn$_4$	30	35	63	32	37	65	35	40	68
Oats$_5$	30	35	42	30	35	42	33	38	45
Oats$_4$	30	35	42	30	35	42	33	38	45
Meadow$_5$	2.2	2.5	3.2	2.2	2.5	3.2	2.2	2.5	3.2
After CCCO or C Sb CO									
Meadow$_4$	2.2	2.5	3.2	2.2	2.5	3.2	2.2	2.5	3.2
Meadow$_5$	2.2	2.5	3.2	2.2	2.5	3.2	2.2	2.5	3.2
After CCOM or C Sb OM									
Meadow$_4$	2.2	2.5	3.2	2.2	2.5	3.2	2.2	2.5	3.2
Corn$_5$	50	55	69	55	60	74	55	60	74
After C Sb O Sb									
Corn$_4$	37	42	[illegible]	39	44	65	42	47	68
Soybeans$_5$	18	22	[illegible]	20	23	26	21	24	27

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Table 20 (Continued)

Conservation:	Land A: No practices			Contours			Terraces		
Fertilizers:	No	Low	High	No	Low	High	No	Low	High
	N P	N P	N P	N P	N P	N P	N P	N P	N P
After MMCC									
Corn$_4$	40	45	63	42	47	65	45	50	68
Corn$_5$	37	42	63	39	44	65	42	47	68
Corn$_4$	40	45	63	42	47	65	45	50	68
Soybeans$_5$	19	23	25	21	24	26	22	25	27
After MMCSb									
Corn$_4$	44	49	68	49	54	71	49	54	71
Soybeans$_5$	19	23	25	21	24	26	22	25	27
Corn$_4$	44	49	69	49	54	71	49	54	71
Corn$_5$	40	45	63	42	47	65	45	50	68
Corn$_4$	44	49	68	49	54	71	49	54	71
Oats$_5$	30	35	42	30	35	42	33	38	45
After COMM									
Corn$_4$	50	55	69	55	60	74	55	60	74
Corn$_5$	43	48	68	48	53	72	48	53	72
	Land B								
After CCC$_3$									
Corn$_4$	22	28	40	25	29	44	25	30	51
Corn$_5$	22	28	40	25	29	44	25	30	51
or CCC Sb									
Corn$_4$	22	28	40	25	29	44	25	30	51
Soybeans$_5$	15	16	19	15	16	19	18	19	21
or CSbOSb									
Corn$_4$	22	28	40	25	29	44	25	30	51
Oats$_5$	20	24	32	21	25	33	21	25	33
Oats$_4$	20	24	32	21	25	33	21	25	33
Meadow$_5$	2.0	2.2	2.8	2.0	2.2	2.8	2.1	2.3	3.0

Table 20 (Continued)

Conservation:	Land B[a]								
	No practices			Contouring			Terracing		
Fertilizers:	No N P	Low N P	High N P	No N P	Low N P	High N P	No N P	Low N P	High N P
After CCCO or CSbCO									
Meadow$_4$	2.0	2.2	2.8	2.0	2.2	2.8	2.1	2.3	3.0
Meadow$_5$	2.0	2.2	2.8	2.0	2.2	2.8	2.1	2.3	3.0
After CCOM or CSbOM									
Meadow$_4$	2.0	2.2	2.8	2.0	2.2	2.8	2.1	2.3	3.0
Corn$_5$	36	41	54	39	44	57	42	47	60
After CSbCSb									
Corn$_4$	28	30	43	28	31	46	30	37	53
Soybeans	15	16	19	15	15	19	18	19	21
After MMCC									
Corn$_4$	30	32	45	31	34	48	35	39	54
Corn$_5$	28	30	43	28	31	46	30	37	53
Corn$_4$	30	32	45	31	34	48	35	39	54
Soybeans$_5$	16	17	19	16	17	19	19	20	21
After MMCSb									
Corn$_4$	32	37	50	35	4	53	38	43	57
Soybeans$_5$	16	17	19	16	17	19	19	20	21
Corn$_4$	32	37	50	35	40	53	38	43	57
Corn$_5$	30	32	45	31	34	48	35	39	54
Corn$_4$	32	37	50	35	40	53	38	43	58
Oats$_5$	20	25	32	21	26	33	24	29	36

Table 20 (Continued)

Conservation: Fertilizers:	Land B: No practices			Contouring			Terracing		
	No N P	Low N P	High N P	No N P	Low N P	High N P	No N P	Low N P	High N P
<u>After COMM</u>									
$Corn_4$	36	41	54	39	44	57	42	47	60
$Corn_5$	30	35	48	33	38	52	38	42	57

Source: Frank F. Riecken, W. F. Shrader and David F. Slusher. Agronomy Department, Iowa State University. Private communication. Feb. 22, 1960

Table 21. Pounds per acre of available nutrients supplied by commercial fertilizers for 1st and 2nd year crops and different conservation and fertilization levels

Practices:	No conservation			Contouring			Terracing		
Fertilizers:	No	Low	High	No	Low	High	No	Low	High
	N P	N P	N P	N P	N P	N P	N P	N P	N P
	Land A					**Marshall 1-5%**			
Rotation									
Corn$_0$		5	35+10		5	35+10		5	35+10
Oats$_1$		0+10	10+0		0+10	10+0		0+10	10+0
Corn$_0$		5	35+10		5	35+10		5	35+10
Soybeans$_1$									
Meadow$_0$			0+10			0+10			0+10
Corn$_1$		5	50+10		5	50+10		5	50+10
Meadow			0+10			0+10			0+10
Corn		5	50+10		5	50+10		5	50+10
Corn$_1$		5	35+10		5	35+10			
	Land B					**Marshall 8-12%**			
Corn$_1$		5	35+25		5	35+25		5	35+25
Oats$_1$		0+10	10+10		0+10	10+10		0+10	10+10
Corn$_0$		5	44+25		5	44+25		5	44+25
Soybeans$_1$			0+10			0+10			0+10
Meadow$_0$			0+10			0+10			0+10
Corn$_1$		5	60+15		5	60+15		5	60+15
Meadow			0+10			0+10			0+10
Corn		5	60+15		5	60+15		5	60+15
Corn$_1$		5	35+25		5	35+25			

Source: John T. Pesek and Frank F. Riecken. Agronomy Department, Iowa State University. Private communication. Feb. 22, 1960

Table 22. Pounds per acre of available nutrients supplied by commercial fertilizers for 3rd and 4th year crops and different conservation and fertilization levels

Land A									
Practices:	No conservation			Contouring			Terracing		
Fertilizers	No N P	Low N P	High N P	No N P	Low N P	High N P	No N P	Low N P	High N P
After C									
Corn		5	50+10		5	50+10		5	50+10
Corn		5	50+10		5	50+10		5	50+10
Corn		5	50+10		5	50+10		5	50+10
Soybeans									
Corn		5	50+10		5	50+10		5	50+10
Oats		0+10	10+0		0+10	10+0		0+10	10+0
Oats		0+10	10+0		0+10	10+0		0+10	10+0
Meadow			0+10			0+10			0+10
After MM									
Corn		5	5+10		5	5+10		5	5+10
Soybeans									
Corn		5	5+10		5	5+10		5	5+10
Corn		5	50+10		5	50+10		5	50+10
After CSb									
Corn		5	35+10		5	35+10		5	35+10
Corn		5	50+10		5	50+10		5	50+10
Corn		5	35+10		5	35+10		5	35+10
Soybeans									

Table 22 (Continued)

Practices:	No conservation			Contouring			Terracing		
Fertilizers:	No	Low	High	No	Low	High	No	Low	High
	N P	N P	N P	N P	N P	N P	N P	N P	N P
After C									
Corn		5	60+15		5	60+15		5	60+15
Corn		5	60+15		5	60+15		5	60+15
Corn		5	60+15		5	60+15		5	60+15
Soybeans			0+10			0+10			0+10
Corn		5	50+10		5	50+10		5	50+10
Oats		0+10	10+10		0+10	10+10		0+10	10+10
Oats		0+10	10+10		0+10	10+10		0+10	10+10
Meadow									
After MM									
Corn		5	5+25		5	5+25		5	5+25
Soybeans			0+10			0+10			0+10
Corn		5	5+25		5	5+25		5	5+25
Corn			60+15			60+15			60+15
After CSb									
Corn		5	50+20		5	50+20		5	50+20
Corn		5	60+15		5	60+15		5	60+15
Corn		5	50+20		5	50+20		5	50+20
Soybeans			0+10			0+10			0+10

Land B

Source: John T. Pesek and Frank F. Riecken. Agronomy Department, Iowa State University. Private communication. Feb. 22, 1960

Table 23. Pounds per acre of available nutrients supplied by commercial fertilizers for 5th and 6th year crops and different conservation and fertilization levels

	Land A								
Practices:	No conservation			Contouring			Terracing		
Fertilizers:	No	Low	High	No	Low	High	No	Low	High
	N P	N P	N P	N P	N P	N P	N P	N P	N P
After CCC or CCSb or CSbCSb									
Corn		5	50+10		5	50+10		5	50+10
Corn		5	50+10		5	50+10		5	50+10
Corn		5	50+10		5	50+10		5	
Soybeans									
Corn		5	50+10		5	50+10		5	50+10
Oats		0+10	10+10		0+10	10+10		0+10	10+10
Oats		0+10	10+10		0+10	10+10		0+10	10+10
Meadow			0+10			0+10			0+10
After CCO or CSbCO									
Meadow			0+10			0+10			0+10
Meadow			0+10			0+10			0+10
After CCOM, C Sb OM									
Meadow			0+10			0+10			0+10
Corn		5	5+10		5	5+10		5	5+10
After CSbCSb									
Corn		5	50+10		5	50+10		5	50+10
Soybeans									

Table 23 (Continued)

	Land A								
Practices:	No conservation			Contouring			Terracing		
Fertilizers:	No	Low	High	No	Low	High	No	Low	High
	N P	N P	N P	N P	N P	N P	N P	N P	N P
After MMCC									
Corn		5	50+10		5	50+10		5	50+10
Corn		5	50+10		5	50+10		5	50+10
Corn		5	50+10		5	50+10		5	50+10
Soybeans									
After MMCSb									
Corn		5	35+10		5	35+10		5	35+10
Soybeans									
Corn		5	35+10		5	35+10		5	35+10
Corn		5	50+10		5	50+10		5	50+10
Corn		5	35+10		5	35+10		5	35+10
Oats		0+10	10+0		0+10	10+0		0+10	10+0
	Land B								
After CCC or CCSb or CSbCSb									
Corn		5	60+15		5	60+15		5	60+15
Corn		5	60+15		5	60+15		5	60+15
Corn		5	60+15		5	60+15		5	60+15
Soybeans			0+10			0+10			0+10
Corn		5	60+15		5	60+15		5	60+15
Oats		0+10	10+10		0+10	10+10		0+10	10+10
Oats		0+10	10+10		0+10	10+10		0+10	10+10

Table 23 (Continued)

	Land B								
Practices:	No conservation			Contouring			Terracing		
Fertilizers:	No	Low	High	No	Low	High	No	Low	High
	N P	N P	N P	N P	N P	N P	N P	N P	N P
After CCCO CSbCO									
Meadow									
Meadow			0+10			0+10			0+10
After CCOM CSbOM									
Meadow									
Corn		5	5+25		5	5+25		5	5+25
After CSbCSb									
Corn		5	60+15		5	60+15		5	60+15
Soybeans			0+10			0+10			0+10
After MMCC									
Corn		5	60+15		5	60+15		5	60+15
Corn		5	60+15		5	60+15		5	60+15
Corn		5	60+15		5	60+15		5	60+15
Soybeans			0+10			0+10			0+10
After MMCSb									
Corn		5	50+20		5	50+20		5	50+20
Soybeans			0+10			0+10			0+10
Corn		5	50+20		5	50+20		5	50+20
Corn		5q	60+15		5	60+15		5	60+15
Corn		5	50+20		5	50+20		5	50+20
Oats		0+10	10+10		0+10	10+10		0+10	10+10

Source: Private communication, John T. Pesej and Frank F,.Riecken, Agronomy Department, Iowa State University. Feb. 22, 1960